IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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Tech 50

IRON AND STEEL EXPOSITION

June 7-10th, 1926 **Hotel Sherman** **Chicago, Ill.**

LIST OF EXHIBITORS

Martindale Electric Company
Johns Manville, Inc.
Mutual Foundry & Machinery Company
The Fleig Corp.
Plibrico Jointless Firebrick Company
Morgan Engineering Company
Electrical Engineers Equipment Company
V. V. Fittings Company
National Carbon Company, Inc.
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Robinson Ventilating Company
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Norma Hoffman Bearings Corporation
Crouse Hinds Company
Appleton Electric Company
Allis Chalmers Manufacturing Company
Edison Storage Battery Company
Electric Controller & Manufacturing Company
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The Clark Controller Company
Keystone Lubricating Company
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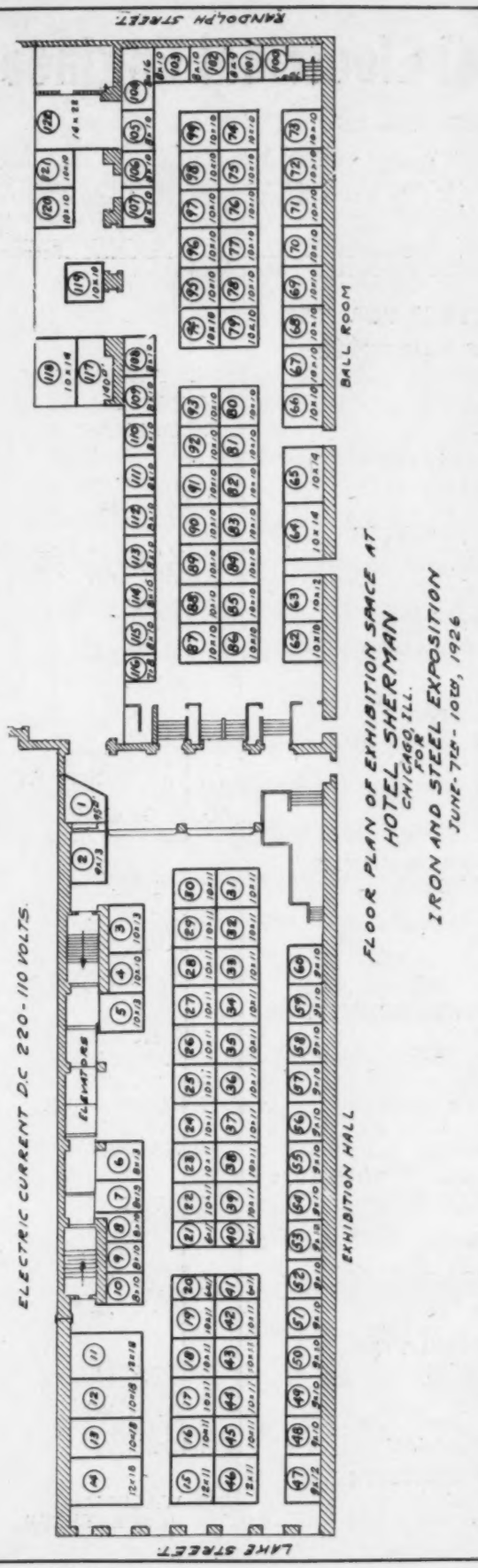

General Headquarters, Hotel Sherman, Chicago, Ill.

Ball Room, Hotel Sherman

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WILLIAM E. DEVER
MAYOR

OFFICE OF THE MAYOR
CITY OF CHICAGO

May 17, 1926.

Association of Iron and Steel Electrical Engineers,
Hotel Sherman,
Chicago, Illinois.

Gentlemen:

As Mayor of the City of Chicago it gives me great pleasure to welcome you upon the occasion of your twenty-second annual convention and exposition being held here.

In choosing Chicago as the place of this year's conclave there must have been conceived in the minds of your membership an acknowledgment of the rapid strides we have made both in the development of the iron and steel industry in Chicago and its environs and in the extensive use of iron and steel products necessary in the construction of skyscrapers in numbers which have completely changed Chicago's skyline.

Your profession epitomizes progress. In a great measure our rapid and sustained growth can be attributed to our having recognized the achievements accomplished by you who have advanced the industry of iron and steel to its present state.

We are, therefore, eager to greet you on this occasion and offer you a diversified assembly of interesting places and things which should attract and engage the attention of the visiting delegates and their families. I feel sure that the hospitality of our citizens and the charm of our community will tend to make your stay a very pleasant one.

Very sincerely yours,
William E. Dever
Mayor.

Twenty-Second Annual Convention and Iron and Steel Exposition

HOTEL SHERMAN **JUNE 7th to 11, 1926** **CHICAGO, ILLINOIS**

Association of Iron and Steel Electrical Engineers

Electrical—Combustion—Safety Divisions

OFFICIAL PROGRAM

Monday June 7th, 1926

9:00 A. M.—Registration—Mezzanine Floor. 10:00 A. M.—Business Session—Crystal Room.

12:30 Noon—General Luncheon—Louis XVI Room.

Electric, Combustion and Safety Divisions, Exhibitors and Guests Invited.

1:30 P. M.—Technical Session—Louis XVI Room.

Auspices—Safety Division—C. L. Baker, Chairman; R. G. Adair, Secretary.

Subject—"Recommendations of A. I. & S. E. E., Covering Rules for the Safe Operation of Electric Overhead Traveling Cranes."

9:00 P. M.—Informal Dance—Louis XVI Room.

R. L. McIntosh, Chairman.

Tuesday, June 8th, 1926

Crystal Room

10:00 A. M.—Electric Transportation Day.

F. O. Schnure, Chairman; F. W. Cramer, Secretary.

Economies of Steel Plant Railroad Electrification, by O. Needham and David C. Hershberger.

Yard Switching and Mill Transportation, by W. P. Potter and G. H. Shapter.

How Electrical Industrial Truck and Tractor Equipment is Effecting Savings in the Iron and Steel Industry, by H. J. Payne.

Wednesday, June 9th, 1926

Crystal Room

REFRACTORIES

10:00 A. M.—H. C. Siebert, Chairman; W. J. Harper, Secretary.

Refractories for Use in Steel Plants, by M. C. Booze.

Open Hearth Roof Construction, by W. J. Harper.

Refractories in Steel Plants, by W. H. Kelly.

Coke Ovens, by M. J. Conway.

Heating Furnaces, E. W. Trexler

PRODUCERS

G. R. McDermott, Chairman; A. G. Witting, Secretary.

Gas Producer Operation, by F. E. Leahy.

STANDARDIZATION

A. C. Cummins, Chairman; R. H. Keil, Secretary.

Standardized Mill Type Motors, by A. C. Cummins, Chairman, Standardization Committee, A. I. & S. E. E.

Thursday, June 10th, 1926

Crystal Room—10:00 A. M.

W. P. Chandler, Chairman; F. C. Watson, Secretary.

The Electric Heat Committee's Report, by W. P. Chandler, Chairman, Electric Heat Committee.

E. S. Jefferies, Chairman; F. W. Cramer, Secretary.

Additions to Rolling Mills, Wheeling Steel Corporation, Steubenville Plant, Steubenville, Ohio, by M. J. Conway.

7:00 P. M.

Formal Dinner Dance—Bal Tabarin

F. H. Kittredge, Chairman.

Friday, June 11th, 1926

H. E. Davis, Chairman.

Inspection Trip

Illinois Steel Company, Gary, Ind.

The Association will be the guests of the Illinois Steel Company.

A Golf Tournament has been arranged through the kindness of the Illinois Steel Company at the Gary Country Club.

EDITORIALS

ACTIVITIES OF AI&SEE

By GEO. H. SCHAEFFER*

IRON and steel are among the few essentials whose present prices are the same as those existing before the war. As a matter of fact, some grades of steel are cheaper now than before the war. The significance of this statement cannot be overestimated. To meet today's market at pre-war prices, or even under, and at the same time pay advanced wages—advanced prices for all material entering into the manufacture—seems like an impossibility. Railroads had to recourse to increased rates, so had practically all other lines of enterprise. The Central Station got the backing of the Public Service Commission—and were

GEORGE H. SCHAEFFER

thus assured of a manufacturing profit. Not so with the Iron and Steel Manufacturer, however, for there was no public commission to authorize increased prices. In fact, the iron and steel tonnage was greatly increased on account of the war—and to keep the plants running at anywhere near capacity meant stimulating a demand at low prices—and the problem resolved itself into a race and that only the most fit or most economical would survive.

There remained only one course open to the Steel Mill Executive. This one course was reducing the costs of production to the point where a margin of profit could exist—sufficient for the character of the business. Economies just had to be made, mill operations had to be cheapened, blast furnaces and waste heat used more economically, and steam had to be used more efficiently. The greatest savings were accomplished in electrification. Today the installation of steam drive for a mill is an exception rather than the rule. The company using steam drive is giving its competitor an advantage which, in many cases, has resulted disastrously.

In this great awakening to the possibilities of economizing by the intelligent application, on a large scale, of the principles of Electrical Engineering, the members of the Association of Iron & Steel Electrical Engineers have taken a very important part. The Association, with its twenty-two years of active steel mill co-operation and participation, deserves no little credit. Reflect for a moment—it is the only engineering organization devoting its activities solely to the Iron & Steel Industry. Its members are engineers actively employed in production and operation. Their problems are those of production and efficient operation—arising from intimate contact with men and machinery—and the solution of such problems generally falls to the operating engineer. The Association was formed with the idea of applying electricity to the Iron and Steel Industry—where it would prove to be the most economical installation. It has bridged the gap between the Steel Mill Executive and the builder of steel mill equipment—first by furnishing first-hand knowledge of steel mill requirements—and second, by applying intelligently electrical engineering principles to these requirements.

Monthly meetings are held in Pittsburgh, Philadelphia, Cleveland, Chicago and Birmingham. Subjects vital to iron and steel are discussed, accepted and rejected. The monthly meetings have developed the membership into a Steel Mill Fraternity. There is always an opportunity for the interchange of ideas—this is in itself a sort of clearing house and avoids useless duplication of experimental work and affords opportunity for checking up on various economies.

In addition to monthly meetings the Association holds a yearly convention—the purpose is to present studies and reports of the various committee activities—which sometimes consist of studies made by committees covering several years—while others comprise an entire field for certain special equipment—and again, another committee will present a study of certain lines of new equipment. The twenty-second Annual Convention, to be held in Chicago in June, will have reports in its technical sessions covering: "Rules for Safe Operation of Overhead Electric Traveling Cranes," "Standardization of Mill Type Motors," "Refractories in Iron and Steel Industry," "Report of Electric Heat Committee" and "Electrical Transportation." In addition to the technical sessions, the Association handles an exhibit—where all the latest developments applying to Steel Mill operation are displayed. In most cases, these exhibits are erected and operated. At close of Convention inspection trips to various Steel Mills will be arranged.

*President Association Iron and Steel Electrical Engineers. Elec. Engr., The Carpenter Steel Co., Reading, Pa.

GORDON FOX
District Secretary, Chicago Section, A.I.&S.E.E.—General Secretary Arrangements Committee.

F. A. WILEY
General Chairman, General Convention Arrangements Committee—Electric Supt., Wisconsin Steel Company, South Chicago, Illinois.

F. H. KITTREDGE
Chairman, Formal Dinner Dance Committee, Electric Superintendent, Illinois Steel Company, Joliet, Illinois.

H. E. DAVIS
Chairman, Inspection Trip and Golf Tournament, Friday. Electric Supt. Interstate Iron & Steel Co., So. Chicago, Ill.

M. J. CONWAY
Combination Engr., Wheeling Steel Corp., Steubenville, Ohio.—Author.

O. NEEDHAM
Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Author.

A FEW THINGS TO THINK ABOUT

By F. W. CRAMER*

IF you should take a census of the operating electrical superintendents in the steel mills, relative to length of service, many would show records dating back to the origin of the electric drive. In these early days, the electrical department was a branch of some other department, and the electrician's job was to keep the lights burning and look after a few small motors. Gradually the department grew, and new problems arose in the electrical line. If a motor was purchased, a control scheme had to be originated. The vast amount of data we now have available on motors and controllers was not in existence at that time, so it was up to the individual to rely upon his own judgment for selecting the proper apparatus, and upon his ingenuity to make it work. To those of us who have made a study of the electrical development in steel mills, the fact is clearly pointed out that these original electricians solved—perhaps only in a crude way—many of the problems we are up against today. But it is also a fact that twenty years ago, it was "every plant for itself." The electrical man in one plant perhaps did not know the man in a similar position at a plant a few miles away. Perhaps they were both working on similar problems at the same time, and each solved them in his own way. If one man desired to visit another plant, he may have been able to get in, and then he may not have been able to. There existed a curtain of secrecy about a lot of things that in reality were not secrets at all. Later is became apparent to some of the leaders in the industry that a common bond existed among the steel mill electrical men, and that by co-operation they could not only help themselves but, at the same time, would be aiding others, but no organization existed through which they could co-operate. Perhaps it was the thought that the railway type motor should be changed in to what we now call the mill type motor that brought about the first meeting of these steel mill electrical men, out of which grew the present Association, and we still list among the members several of those who attended this first informal gathering.

If you look back over the yearly proceedings from that meeting in 1908, down to the present time, you can notice a change of attitude taking place—the willingness to interchange ideas, and to co-operate among the different plants. In the early days, the various managements did not give the Association the recognition they do at the present time, and perhaps the representatives were not free to express their opinions in meetings. The work of the organization was carried on only by men who were busily employed in the mills, and the job of "selling" the Association was a big proposition. What they needed most was the support of the electrical men in the mills who were willing and able to tell of their installations, and be willing to interchange ideas with other mills. As the years passed it gradually became a custom that when a mill was to purchase new equipment, it inquired of other mills to learn if they had similar apparatus, and if so what its shortcomings and good features were.

Fostering this movement was the Association, and its publications contain the development, step by step, of modern mill drives. The men who actively assisted in this movement were the men who are now the leaders of the industry, and they have seen it progress until at the present time, records have been compiled and data secured from every type of drive and control in the steel industry. It is data which no manufacturing organization could have secured, because most of it was contributed by the active members—the men who bought and operated the equipment. These men have been the backbone of the organization, and have the betterment of the electrical department not only as their occupation but also as their chief aim in life.

Let us take the case a little further and note what has happened when practically every steel mill electrical superintendent was "sold" on the Association, and was co-operating in the advancement of the profession. These leaders early saw the great benefit that could be derived in the plants by a close association with the men who supplied the steam for the turbines, and had charge of combustion, so the "Fuel" section was organized, and co-operation in the steel mills advanced a step further. This addition brought new life and ideas into the Association, and their value was recognized to such an extent that practically all the "Fuel" men of the industry are now listed among our members. Having perfected this expansion, the safety and welfare of the electrical employees, a problem that had always been given deep consideration, was studied with a view of giving more thought to accident hazards, and as a result, the steel mill safety men were invited into the organization. Now this has been accomplished, and co-operation and advancement of the steel mill electrical profession has gone on further.

Now, the point we wish to impress is the fact that by a lot of tiresome, and at times unthanked, energy has been given by the pioneers of the industry that has made it possible for you to know what the other fellow is doing, and what he has, and secure a warm welcome for you when you visit his plant. If you have not made use of the vast amount of information that the Association has compiled, and the opportunities for interchange of ideas which it offers, you have overlooked the best bet in your profession.

The leaders of the organization have always been, and will always be steel mill men. The more interest the active member takes, the more benefit he will derive, and the more expansion and value the Association will have to the industry.

We can summarize all of the above by saying "Use the Association;" be both a giver and a receiver, and yourself, your plant, and all the other plants will divide the benefit.

*Asst. Elec. Supt., Bethlehem Steel Corp., Johnstown, Pa.

GROWTH OF THE AI&SEE

By R. S. SHOEMAKER*

Frequently I have been asked by those who have noticed the steady growth and increasing influence of the Association of Iron & Steel Electrical Engineers the following questions, which I will attempt

*Supt. Maint., American Rolling Mill Co., Middletown, O.

CONVENTION COMMITTEES

Association of Iron and Steel Electrical Engineers

June 7th to 10th, 1926

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FRIDAY—STEEL MILL INSPECTION AND GOLF TRIP

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to answer with as much detail as the space alloted me will permit.

How can you continue, year after year, to increase your membership and extend the scope of your activities by the organization from time to time of new sections, such as the Combustion Section and the more recently organized Safety Section?

How can you do these things and still maintain a sound financial status in the face of the increasing competition you must have from the other National Engineering Societies?

While it may seem at first glance rather difficult to answer these questions, yet, they are in reality, quite easily explained.

Fundamentally, the secret of our success today and ever has been, that we have had ever since the day of our inception the firm belief that (and it

R. S. SHOEMAKER

has been growing stronger each year), as an association, we should have to do only with those problems arising within the Iron & Steel industry.

We have always maintained this policy and I feel safe in stating that we always shall. I make this very positive statement even though we have frequently been approached by other engineering societies who have expressed a very marked desire for us to consolidate with them. Several movements have been set on foot to maneuver us into a position where we would of ourselves desire such consolidation.

After nineteen years of undivided service to the Iron & Steel Industry, we feel more than ever that our policy, of "No entangling alliances," has worked to the best interests of all concerned. The increasing appreciation and respect shown us as an association by the leaders of the Steel industry, fully compensates us for our efforts.

For very close to two decades, the Iron & Steel Engineers have been an integral part of the industry. During this period has been witnessed a greater advancement in the art of steel making than during any other period of it's history. In the development of the vast tonnages of Iron, Steel and Alloy metals in common use today, the A. I. & S. E. E., with their Combustion and Safety Sections, feel that they have had a very necessary and vital part and through the medium of their yearly proceedings and the Iron & Steel Engineer, that they have established a worthy and permanent record.

The answer to the question of our increasing membership is simply that we have had a natural growth, year by year, in direct proportion to the growth of the basic industry. We could not have decreased or held stationary our membership had we so desired.

Likewise, our expansion within the last several years to include the Combustion Engineers, Chief Engineers, General Superintendents, etc., has come about through a natural demand from these men for a medium wherein they might exchange ideas and discuss their problems and extend their personal acquaintance with men holding similar positions, and establish better contacts with the manufacturers.

For me to state here in any detail how successful the Combustion Section has been and to what extent it is filling a real need, would be superfluous. Our published record of the proceedings of this section speaks for itself.

The organization during this year of the Safety Section, came about in exactly the same manner, and due to the same reasons expressed by the Safety Engineers of our companies.

While there has been only one general meeting of this section, yet, judging from the intense interest displayed and the valuable discussion which was brought out, and the surprisingly large attendance of practically all steel mill Safety Engineers, it is safe to say that this section will be equally successful.

The last question, as to how we are able to continue these activities and still maintain a sound financial status in the fact of competition, is also very easily accounted for.

In answering this question let me first state that we do not have any competition from any other engineering societies. We are a self-contained, self-supporting organization, wholly within the Iron & Steel industry and with every intention of so remaining, and are the only organization of its kind.

Our revenues, which are used entirely for the distribution of engineering knowledge within the industry, is derived from three main sources. Our membership dues are a real asset, because, while they are not high as in some other societies, they are promptly paid, because the rank and file are satisfied that they get large returns for their money. Our magazine, The Iron & Steel Engineer, which carries our monthly proceedings, has been from the start self-sustaining, and revenue from its publication helps in a measure to defray some of our other publication costs.

For a number of years it has been our practice to hold an annual convention, and to combine with

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Chairman, Safety Division, A.I.&S.E.E.

H. J. PAYNE
Electric Industrial Truck Dept., The Society for Electrical Developments, Inc. New York, N. Y.—Author.

F. E. LEAHY
Power Engr., Pittsburgh Plants, National Tube Company, Pittsburgh, Pa.
Author.

C. S. PROUDFOOT
Genl. Mgr., United States Ferro Alloys Company, Niagara Falls, N. Y.
Chairman, Papers Committee.

W. P. POTTER
Chief Engr., Railway Department, General Electric Company, Schenectady, N. Y.
Author.

it an exhibition of considerable magnitude. Because these exhibitions have always been efficiently conducted and have exhibited only apparatus of real constructive interest to the Iron & Steel fraternity, they have been successful and help to keep our books balanced.

THE ELECTRICAL ENGINEER IN THE STEEL INDUSTRY TODAY

By A. J. STANDING*

THE approach of this, the Twenty-second Annual Convention of the Association of Iron and Steel Electrical Engineers, to be held in Chicago in June, marks the passing of another year of our activity and prompts us to stop and take stock, as it were, of the status and present functions of the Iron and Steel Electrical Engineer.

The primary function of the Steel Mill Electrical Department was and still is, the maintenance

A. J. STANDING

of equipment in such operating condition that the continuity of the various steel manufacturing processes will not be unnecessarily interrupted by delays occasioned through failure of the equipment or organization under the control of the operating Electric Engineer.

There is, however, a greater and farther reaching phase that parallels the maintenance of equipment, and that is the obligation which rests on each one of us to continually strive toward reduction of the costs which we must necessarily place upon each ton of steel produced.

With an organization so lined up that the questions of anticipating operating delays and reducing those which seem inevitable receive prompt and skillful attention, the head of the Electric Department can well devote some of his time and attention to the various outstanding features of the cost problem as they are affected by the work of his department. It is upon a few of these items I want to touch briefly at this time.

*Elec. Engr., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.

While we are at about the thirty-second milestone along the road of Steel Mill electrification, it is in reality only about twenty years since what we might term the more intensive application of electricity to the Steel Industry has been taking place. The deficiencies of earlier applications using the then general commercial electrical equipment very definitely pointed the way to greater possibilities in operation, reduction in man power, and especially reduction in operating costs which might be realized by the design and careful application of more rugged electrical apparatus especially fitted to the exacting demands of Steel Mill service.

In the desire for something better and the resulting periods of transition from one development to another, there is ever present that one dominant question of the cost of spare parts required to maintain existing equipment, as compared to the cost of replacing such equipment with new and better apparatus, giving longer life and greater freedom from failures, but adding its burden of cost of additional spare parts, none of which may be interchangeable with the old parts. The realization of this spare part cost has led each of us to attempt to standardize the equipment in our plants and thus permit our spare parts to protect a greater amount of equipment at a lower unit cost.

Our Association, through the medium of the various committees, is trying to consolidate the work of the individuals along the lines of standardization of the electrical equipment used in the Steel Industry, not to the point of discouraging advances in the design and development of better apparatus, but rather with the view of guiding such development along the lines of least additional cost to the Steel Plants.

NEW PRODUCTIONS

By S. S. WALES*

THE Association of Iron & Steel Electrical Engineers is well known to be an Engineering Society, and as such should keep its meetings and publications free from commercialism which would savor of partiality or so-called free advertising of the products of Electric Manufacturer Companies.

The duties of the Association to its members, however, seem to me to be somewhat broader than a literal interpretation of this statement would indicate. The desire of all active, operating members is not only for information as to the proper technical procedure, covering cases under their immediate observation, but also the experience of the other members who may have had a similar problem.

It is impossible to entirely divorce the solution of a problem from the equipment which has aided in accomplishinig it, and this would naturally lead in special cases to the actual specification of Manufacturer, name and the trade designation of the apparatus used, both in written papers and verbal discussions. An operator cannot always be impartial as to whose generators, motor or switch-

*Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.

W. P. CHANDLER, Jr.
Spec. Engr., Carnegie Steel Company, Pittsburgh, Pa. Chairman, Electric Heat Committee.

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Elect. Engr., Illinois Steel Company, South Chicago, Illinois
Chairman, General Invitation Committee.

DAVID C. HERSHBERGER
Engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Author.

A. R. LINTERN
Dist. Sec., Cleveland Section, A.I.&S.E.E.
Floor Manager, Iron & Steel Exposition.

A. C. CUMMINS
Elect. Engr., Carnegie Stel Company, Duquesne, Pa.
Chairman, Standardization Committee.

J. A. OARTEL
Chief Safety Director, Carnegie Steel Co., Pittsburgh, Pa. Chairman, Membership Committee, Safety Division.

board material he uses, and has a right to express his views.

Going a little further I feel that the Association owes to its members to "broadcast" such new productions, as in the judgment of the board of directors, have special merit or are radical departure from so-called standard methods and practice. Being willing, however, to perform this same function for all manufacturers in as far as time and space will permit, the failure of any company to have its developments brought to the attention

S. S. WALES

of the membership of the Association in this manner, is due not to the disinclination of its attention when any new thing is produced.

It is the endeavor of your directors and Papers Committee to balance the three branches, technical, practical and commercial, with a view to keeping all members abreast of the times, both as to methods, equipments and costs, as an engineer today is not simply a man who does things by machinery, but one who applies mechanical equipment so as to save money, in which sense we all become commercialized.

ELECTRIFICATION

By R. S. SAUDEY*

The development of the electrical field is responsible for the progress made in the industrial world, for without it manufacturing would be greatly curtailed.

There is hardly an industry to be found today that does not owe its success to the development of some piece of electrical apparatus which it uses, whether it be an electric light or an intricate piece of electrical apparatus.

The application of electric motors has replaced many of the hand methods of manufacture. The use of welding has done much for industry—both in the manufacture of articles and the salvaging of broken parts, which might otherwise be scrapped.

The appplication of electric heat has made rapid strides in the last few years and has a very promising future. From the small household electrical appliances, to the large electric furnaces in the steel industry, the development of electrical heating apparatus has been very successful. For uniform results no fuel-fired apparatus can compete with the electric heat application, and while the cost is greater in some cases, the quality of the product is more uniform than that obtained by other fuel-fired methods.

With the central power stations spreading their network of power lines out into the rural districts and the linking together of their lines, a greater field is opened up to serve communities which could not afford a central station of their own.

In localities served by the large central stations, current can be bought at a price far below that which the average manufacturer could generate his own power.

The electrification of the foundries has proved successful from the standpoint of quality and production.

The electric drives for the steel mills have replaced the steam engines and have contributed their part to the advancement in the art of steel making. The steel mills use some of the largest motors ever built and they are more dependable than the steam engines formerly used.

The electrical engineer of today has an unlimited field in which to work, and while he has made rapid advancement in his art in the last few years, there is still much work to be done.

There are but few who have contributed more to the advancement of the electrical field than the Association of Iron and Steel Electrical Engineers.

*Chief Elect., Van Dorn Iron Works, Cleveland, Ohio.

"THE BIG FOUR OF SAFETY"

By JOHN A. OARTEL*

IN a recent book on psychology the author calls attention to the wonderful progress of science in material things. He also calls attention to the lack of progress on the spiritual side, except in abstract thinking. It is true that a number of beautiful theories have been thought out and developed for the guidance of man along moral and spiritual lines and in intercourse with his fellowmen—and yet compared to the applications of science on the material side, which have enriched our work and our pleasure to a marvelous degree, we are still in the dark ages in our dealings with our fellowmen. We are still creatures of hate and fear and distrust and prejudice. However, in order not to paint too dark a picture, and also for fear of being called a pessimist, which I am not—decidedly not—I wish to call attention to a movement in the Iron and Steel Industry that has, in my opinion, done more to promote good feeling and co-operation between employer and employe than any other thing. I refer to Safety which has proven to be a happy medium for promoting Contact, Conference, Confidence and Co-operation between employer and employe. The enthronement of this "Big Four" in industry has resulted in adapting and working out, in a very happy way, the ideals of the constructive thinker, which if merely thought

*Chief of Safety Bureau, Carnegie Steel Co., Director National Safety Council; President Western Pennsylvania Division National Safety Council; President Pennsylvania Society of Safety Engineers.

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A. I. & S. E. E. Recommendations

Covering

Rules for the Safe Operation of Electric Overhead Traveling Cranes*

RULES FOR CRANE OPERATORS

(1) The operator should be examined by a Foreman or someone designated in order that his familiarity with crane parts and their uses, as well as his ability to safely operate the crane may be determined in practice and certified to by the examiner.

(2) The operator shall enter or leave his crane at the designated places, making use of the steps or ladder provided at those locations and having both hands free. All materials too large to be carried in pockets shall be raised and lowered by means of a hand line. The hand line must not be attached to the person of the operator.

(3) No one but the craneman shall be allowed in the cage except for repairs, inspection, or instruction of new men or for safety of men working on the crane runway.

(4) The operator shall keep his crane clean and free from all loose boards, tools, bolts, or other objects which may fall on men below or may cause tripping and falling of repairmen when working on the crane.

(5) The operator should inspect his crane at the beginning of the turn or at least once each shift and report at once, any mechanical or electrical defects, especially noting the condition of cables, limit switches, signal gongs and collector shoes.

(6) The operator shall be responsible for the proper oiling and greasing of his crane and he should report any defects in the oiling system on any part of the crane.

(7) The operator, when about to handle material with his crane, shall devote his entire attention to his work and shall pay careful attention to the following points:

(A) Is the hitch of proper length and is it safe?

(B) Is the signal given by the proper party and does the operator understand the signal? If in doubt he must not operate.

(C) Can the load be carried without passing over the heads of men?

(D) Will load clear all obstacles?

(E) Test brakes by means of a short lift and return of controllers to "off" position.

(F) Allow no one to ride the hook or load.

(G) If craneman discovers men on crane runway, he should stop his crane until proper protection is provided.

(8) The operator shall avoid bumping other cranes on the runway, but if he is ordered to do so, he must move the crane slowly with regard to the safety of men working on or below the idle crane.

(9) The operator must not make side pulls unless ordered to do so by a Foreman.

(10) The operator must be sure that his controllers are in the (off) position and switch opened before leaving the crane, and in case of failure of power the controllers must be immediately set in the "Off" position.

(11) In case a controller sticks the operator must pull the main switch at once.

(12) While repairs are being made to the crane, the operator must stay on the job and help with repairs. If ordered to remain in the cage, he must not operate any motion unless he is told that every one is safe.

(13) When the operator is inspecting, repairing, or lubricating his crane, the main switch must be locked in the "off" position.

(14) In case of a fire on the crane, the operator must use the fire extinguisher provided and must notify the Foreman, who shall see that the extinguisher is refilled promptly.

(15) An operator must not operate his crane if he is not physically fit to do so. He should report to his Foreman at once.

(16) The operator must signify his understanding of these rules and must realize that they are intended to help him safeguard the lives of his fellowmen.

RULES FOR FLOORMEN

(1) Floormen when signaling to the crane operator must use the approved crane signals and above all, they must be sure that they do not confuse the operator.

(2) Floormen must be responsible for all slings, chains and hooks and for their proper use in order to make safe hitches, bearing in mind the capacity of the slings and of the crane.

(3) Floormen shall be sure that the crane trolley is centered over the lift in order to prevent swinging of the load.

(4) Floormen must adjust the slings and chains so that they will not strike men on the ground when the crane is moving without a load.

(5) Floormen shall not ride the hook or load or permit others to do so.

(6) An extra man should be in the crane cage to warn the operator when men are working on the crane runway except where approved track torpedoes are used.

*Proposed by Safety and Electrical Divisions of A. I. & S. E. E. for adoption at 22nd Annual Convention, June 7, 1926, Hotel Sherman, Chicago, Ill.

*Report of Electric Heat Committee For 1926**

W. P. CHANDLER, JR., Chairman†

THE Association of Iron and Steel Electrical Engineers recognized, very early, the great possibilities of electric power as a heating medium, and for the past eight years the annual reports of the Committee appointed to follow the development in this field have been of inestimable value to the industry. Each year has seen many new applications and papers dealing with the more important of these developments and have become regular features on the programs of the various sections of our Association.

Next to labor, fuel is the largest single item of expense in the conversion of iron ore to finished steel. During the past ten years, the cost of electric power has increased proportionately less than any other fuel, due to the rapid growth of efficient generating methods. It is small wonder that the steel mill executive, always anxious to reduce operating costs, considers the possibilities of this new fuel more seriously each year.

New applications of electric power as fuel will always be of primary importance to operators interested in more economical production methods. As a rule, the various ramifications and details of new applications are of such importance that a whole paper should be devoted to the subject, and the annual report of the Electric Heat Committee can only briefly call attention to such developments. The expansion of standard equipment is taking place most rapidly and companies having such apparatus or contemplating its use are vitally interested in the success or failure of similar installations. In some few cases, the application of electric heat is in connection with a process which is a trade secret, but the vast majority are in connection with processes differing but slightly in the various plants. It would be of mutual advantage, therefore, to have a clearing house for information and it is in this capacity that the greatest effort has been made by the present Electric Heat Committee. The success of such a proceedure depends entirely on the co-operation of the various companies in the industry, and the replies to our inquiries which we have received are most encouraging. As time goes on it is hoped that the spirit of co-operation will grow and that more information of a definite nature may be obtained especially regarding comparative economies between electric power and other fuels.

The manufacturers of electric heat equipment and the central power stations furnishing the electric power as well should realize that if electric heat is an economic success, the presentation of the results in such a report as this will receive more careful consideration by those in the industry contemplating its use than in any other manner.

When companies with something to sell, either equipment or power, advertise the advantages of electric heat and yet state as in one case that they have no data available which might be of value in such a report as this, it would seem apparent that they were advertising something that was the style rather than an application with sound economic reasons behind it.

It is the object of this report to present the true case of electric heat, and to amplify the statement from year to year. As such, the report should be welcomed by buyer and seller of electric heat equipment and power alike. And since each should derive a benefit from the report each should lend a hand in its preparation by presenting the facts of electric heat as they are associated with it. The company which continually expects to receive without any contributions is like the miser who hoards his gold and loses the best of life, the cordial relations with his fellowmen.

The subject matter comprising the report for the current year has been grouped into certain divisions depending on the method of heat generation and the operation to be accomplished. In order to present the subject from both sides, the committee has endeavored to obtain statements from the various manufacturers relative to the progress made in each group of equipment during the past year as well as statements from the companies having installations as to the advantages or economies obtained.

We wish at this time to express our thanks to those companies and individuals who have co-operated with us by furnishing the information and statements comprising the body of this report.

GENERAL

Statement by Central Power Station Duquesne Light Company

"The following is a list of advantages of Electric Heat treatment as stated by our customers:

Absolute temperature control.
Uniform heating throughout the furnace.
Cleanliness of the product and furnace room.
Uniformity of product.
Simplicity of operation.
Improved working conditions.
Saving of space.
Less maintenance.
Duplication of product.

"There has been a steady increase in both electric heat treating and melting furnaces on our lines in the past three years which indicates to us that industry is beginning to recognize the superiority of electric heat. The inquiries we receive from time to time concerning electric heat leads us to believe that the possibilities of this form of heat has not been sufficiently advertised. We are at present attempting to educate our consumers by presenting in letter form its salient features. These letters are followed by personal calls to the most likely users of electric heat, giving detailed information concerning the particular application involved.

Our electric steel melting load in operation at present totals 31,500 KW and approximately 65 tons. There is also connected a 1260 KW brass melting load of 3700 pounds capacity. The heat treating, japaning, enameling and miscellaneous load total 3050 KW. We supply, therefore, a total of 35,810 KW of electric heat.

*The Electric Heat Committee, in publishing the statements contained in the Report, desires to present the views of individual users of electric heat, and does not assume responsibility for them.

†Special Engineer, Carnegie Steel Co., Pittsburgh, Pa.

ARC MELTING FURNACES*

Arc melting furnaces have been in use in the steel industry for the past twenty years and during that time many types of construction and operation have been tried out. Previous reports of the Electric Heat Committee of this Association have given detailed descriptions of the furnace construction, control and operation. Such details will therefore be omitted from the present report.

The use of arc melting furnaces in the steel industry has developed in two distinct branches, the production of ferro-alloy steels, and the steel foundry. In the case of the former, the ease with which the temperature, alloy additions, and slag compositions can be controlled, coupled with a much higher market price allows the use of the high priced fuel. However, except in some few special cases, large tonnage production of plain carbon steels in electric furnaces in competition with other fuel fired furnaces, would not be very productive of dividends.

The use of the arc furnace in the steel foundry has been steadily growing. Many installations have not resulted in the expected economies. This was due principally to the mis-applications brought about by the diversity of furnace construction and operation which existed at one time. As an illustration, out of 10 or 11 melting furnace installations in Cleveland, only three are in operation at this time. On the other hand, the first installation in Cleveland, and one of the oldest in the steel casting industry, is still in operation. Between 16,000 and 17,000 heats have been taken from this furnace and it still has the original shell, mechanism, winches and holders in use. It is a one-ton Heroult furnace and the sole melting unit in a steel castings company. The owner states that the current consumption was about 600 KW hours per ton and the electrode consumption about 14 pounds per ton. When asked if he would ever go to converter practice, he replied "No." In a foundry operating only during the day, the electric furnace allows a more continuous supply of steel, with more rapid melting and with lower stand by losses that a fuel fired open hearth. To emphasize this statement the following tabulation gives a day's production by a 3-ton electric furnace, starting from cold and operating 12 hours.

Heat No.	Duration	Hrs.	Min.	Weight	KWH	KWH per Ton
1	4:00 to 6:00	2	0	6650	2380	716
2	6:15 to 8:00	1	45	6520	2000	613
3	8:10 to 9:50	1	40	6590	2020	613
4	10:00 to 11:30	1	30	6475	1550	470
5	11:32 to 1:00	1	25	6385	1650	517
6	1:10 to 2:32	1	25	6370	1670	524
7	2:50 to 4:00	1	10	4000	1310	655

Judging from the new installations made and the continuance of existing installations in operation, the electric arc furnace is an economical furnace for the production of steel castings.

In another foundry field the production of gray iron castings it would appear as though the electric arc furnace would find its most fitting application. The furnace is rapidly increasing in favor and has proven successful in every case that can be traced. Its adoption in this field allows one furnace to supply either iron or steel. It is possible to use scrap unsuitable for cupalo practice, and at the same time reduce the cost per ton of castings by a very substantial amount.

*Iron and Steel Engineer, July 1926.

Statement by Pittsburgh Electric Furnace Corporation:

1. The past eighteen months have witnessed a renewal of interest in the possibilities of duplexing with the electric arc furnace. This year a contract has been let for the installation of a twenty-five ton furnace for duplexing on special steels from Open Hearth for the making of ingots. It is natural to expect that the improvement in design of electric furnaces in the past few years will have a very favorable effect on the economics to be obtained by operating in this way.

2. Another very large industrial plant has gone even further and is installing two fifteen-ton furnaces, duplexing on iron from blast furnace metal. The tendency to the installation of large furnaces, particularly in the larger steel plants, is evidenced by the practical completion of a six-tone basic electric, especially adapted to meet the needs of the particular plant in which it is being installed.

3. Duplexing from open hearth is being carried out in one plant on a comparatively small scale, in a 1½-ton electric furnace, and with results which promise to warrant the continuance of the practice.

4. With the advent of more and more continuous molding and the introduction of permanent mold machines, there has risen a need for some more continuous supply of hot metal in quantities suitable to the output of these machines. Batch operation is usually unsuitable for these improved molding methods and various schemes of continuous pouring have been developed. In brief, they involve the maintaining of a constant bath of liquid metal with definite amounts of metal tapped at equal intervals and a like amount of cold scrap added immediately after each tap. Duplexing hot metal is particularly adaptable to schemes of operation which require a continuous delivery of metal to the pouring floor.

5. There has been a continuance of interest in the application of the electric arc furnace to gray iron and special irons. A large percentage of the recent installations have been devoted entirely or in part to work on iron. It is only natural that the superior product of the electric steel furnace should attract attention to its use on iron.

6. The alloying of iron presents a wide range of possibilities. The electric furnace naturally presents an unparalleled means for the successful introduction of alloys under close control and with low alloy losses.

7. Quite aside from the improved characteristics of electric furnace iron, there is an advantage in the use of the electric furnace due to the fact that all scrap charges can be used to produce as good a grade of iron as can be obtained from pig.

8. The fact that a high percentage of borings may be used in the electric furnace charges has opened the way to a profitable disposal of this machine shop waste in several plants.

9. Of particular interest is the recent installation and operation of a series of electric arc furnaces duplexing malleable iron from cupalos on a continuous process. While this installation is unusual because of the large tonnage to be handled, results bid fair to have a marked effect on malleable practice generally.

Statement of E. T. Moore, Consulting Engr.

A new electric steel melting furnace has recently been installed and placed in operation at the plant of the Reading Steel Casting Company, Reading, Pa. It is to be used for making steel castings as well as ingots, and while this particular installation has a capacity up to 15 tons, it is adaptable for any tonnage. This furnace, to be known as the "Edmoore" Electric

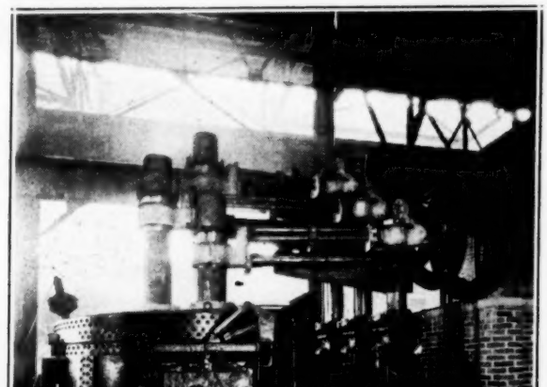


FIG. 1.

Furnace* has many unique features, many of which have never been used before.

The furnace shell for this installation which has a diameter of 12½ feet, is carried in a saddle which is accurately machined, and to which are fastened the rockers, which in turn are machined and roll on machined rocker bases. This saddle and rockers are designed to carry the entire weight of the furnace and charge, the shell itself not being depended upon to carry the weight as is usual practice. The component parts of the saddle are designed so that they all automatically lock together and no bolts or rivets carry any of the load, their only function being to hold the various parts in their proper positions. Likewise, where these parts attach to the furnace shell they are designed that only small lugs or ears actually come in contact with the shell, the main part of the members being so arranged as to give a chimney effect and cause air to circulate between the members and shell, thus doing away with hot spots on the furnace shell and brickwork within the furnace.

By virtue of its design, very small and shallow foundations are required, thereby reducing the cost of installation very materially. By proper proportionings of the radius of the rocker arm and the location of its axis with respect to the furnace shell the spout is made to travel in almost a vertical line so that it is not necessary to rack the ladle as the furnace advances in its tilting.

Another very important feature is the fact that the masts which support the electrode arms or gibs as well as the electrodes, are not secured to the furnace shell but are made independent of the furnace proper (Fig 1). This removes a great mass of metal from the shell of the furnace which always serves to accumulate a large amount of heat. Also, by this method much less head room is required when tilting the furnace, since the masts are stationary and do not tilt with the furnace. This is a very decided advantage in many plant as there is frequently limitation as to head room.

Because of the fact that the masts are separately mounted, it is necessary to remove the electrodes from the furnace when tilting (Fig. 2). This is done with the electrode motors, and when the electrodes have reached a predetermined height, they are automatically rotated to one side away from the furnace proper so that it may be tilted. This construction also offers the great advantage in that it may be charged mechanically by lifting or swinging the roof from the furnace, leaving it unobstructed for charging through the top with a bottom dumping bucket handled by a crane. The furnace, however, is arranged so that it may be charged mechanically by an open hearth charging machine or similar device through the charging door of the furnace. This charging door has a special feature of air cooling which prolongs the life of the brickwork on the inside of the door.

The electrode motors and reduction gears which raise and lower the electrodes are installed remote from the furnace where they are accessible and may be properly and easily inspected and maintained. These units are practically noiseless and have an unusually wide range of speed, as may be predetermined by a special controller arranged for this purpose.

FIG. 2.

The design of the electrode holders departs very materially from those now on the market in that they are of the wedge self-locking type and no bolts or springs are used in their construction, the electrode automatically locking itself in place. The electrode holders are also designed so that they automatically lock on to the arm or gib and no bolts are required

*Registered trade mark.

to hold them in place. This is the first time this method has ever been attempted and is a very decided advantage from an operating standpoint in saving time. The electrode holders and roof rings are made of aluminum, which is also a very radical departure and not only reduce the weight but act as more efficient cooling mediums.

The furnace is equipped with proper limit switches so that the electrodes cannot be swung unless the furnace is in neutral or normal position and when pouring a heat the electrodes cannot be operated until the furnace has again been restored to normal position.

The flexible cables carrying the current from the transformer busses to the furnace have tapered lugs forged on each end of the individual cables, which is the first time this method has been used on an electric steel furnace. By this method considerably better contact is secured with absence of heating and current waste.

The transformer used with the furnace in this installation has a capacity of 4500 KVA available during the melting period and is a 3-phase self-cooled unit. Voltages up to 170 can be selected for melting and practically any voltage from this limit down to 80 Volts may be used for refining.

The "Edmoore" Electric Furnace has been designed to eliminate many of the operating difficulties generally experienced as well as providing a custom-made unit and to fit in with limiting conditions in building structures.

Statement by The Timken Roller Bearing Company:

Started in a small way some 10 years ago with the object of insuring a dependable supply of quality steel for Timken Bearings, the Timken Steel Mill has developed into one of the largest producers of electric alloy steel in the country. Not only does it produce all the steel that enters into Timken Bearings, but it is also producing a considerable and steadily increasing tonnage of special alloy steels for the automotive and allied trades which have been quick to appreciate the advantages of buying steel from a concern which itself fabricates into finished product a large proportion of the steel it produces.

Timken Steel is made by the basic Electric Process, which, it is generally recognized, lends itself better than any other to the commercial production in tonnage lots of the highest grade steels.

In the last analysis, the superiority of basic electric steel may be attributed to the fact that the basic electric process is the only one in which the steel is finished under a slag that is actually reducing in nature. In all other processes the finishing slags are more or less oxidizing or at the best neutral in character.

The presence of the reducing slag is directly responsible for most of the advantages of the basic electric process. The most important features made possible by the reducing slag are:

1. Deoxidation degasification and cleansing of the steel may be carried out in the furnace to a degree unapproached by any other process, except the crucible process.

2. Alloy additions may be made in the furnace without appreciable loss. Because of this, alloy additions may be made early, thus allowing plenty of time for diffusion, etc. This feature makes it possible to control analysis within closer limits than is possible with other processes.

3. Sulphur may be reduced positively to a very low limit. In no other process may sulphur elmination be said to be so positive.

Another practical and important advantage made possible by electric heating is close regulation of refining and tapping temperatures.

Steel Melting Department

The Melting Department of the Timken Roller Bearing Company includes five basic lined Heroult furnaces, which although nominally of 6 tons capacity are regularly turning out 8-ton heats. As is well, known, the Heroult is an arc furnace in which the heat is generated in the arcs struck between each of three vertical electrodes and the metallic charge, supplemented by a certain amount of heat generated by the passage of the current through the metallic charge. Three phase current is used, one phase being connected to each electrode. The electrodes are of amorphous carbon and are 17 inches in dimeter.

Current at 22,000 volts is led to 2,500 KVA double voltage transformers at each of the furnaces where it is stepped down to 170 volts for the melting and 100 volts for the finishing periods. During the melting period a current of about 10,000 amps. per phase at 170 volts is applied and maintained until the charge is almost all melted when the voltage is reduced to 100 in order to avoid burning the furnace lining. Automotive electrode control is used on all furnaces. A furnace lining lasts about 75 heats and the roof about half as long. Electrode consumption averages about 18 pounds per net ton of ingots.

As a result of the heavy power input during the melting period, a 19,000-pound charge is melted within 1½ hours after the power is applied. This rapid meltdown, aided by efficient charging crews and furnace helpers, enable us to get a much greater production per furnace than was formerly thought possible. It is hardly necessary to point out that from a quality standpoint rapid melting is desirable in that it tends to reduce oxidation.

The furnaces are served by two 20-ton ladle cranes and one 10-ton crane for general use. From 10-ton ladles, the steel is poured through 1-inch nozzles into 19-inch corrugated Gathman molds. A refractory hot top is used in all cases. The ingot, which is poured big end up, weighs 4,250 pounds, hot top included. A 75-ton inverted stripper serves to strip any ingots that may stick in the molds.

INDUCTION FURNACES

The development of the induction furnace and especially electrical equipment which will place an installation on an economical basis offers great possibilities in the field of electrical heating.

So far its development and application has been confined principally to the non-ferrous industry, the production of carbon free ferrous alloys, and to experimental laboratory work. This is the natural result of the inherent advantages which Dr. E. F. Northrup has classified as the leading features of high-frequency inductive heating.

1. Energy and energy only enters the mass to be heated—which may have the form of a solid cylinder

—by way of that portion of its surface which is covered by the coil.

2. If the condition is met that the mass have proper size and resistivity, all of the inflowing energy is converted into heat within it.

3. The ratio of the power component to the reactive component is determined chiefly by the coupling. In other words, close coupling and high power factor go together.

4. The efficiency of an ironless inductive furnace is quite equal theoretically to that of an induction furnace which uses transformer iron. The electrical efficiency of the ironless induction furnace may be made about the same for furnaces of different sizes, though the melting efficiency of large furnaces may become considerably greater than that of small furnaces.

5. The successful functioning of the ironless induction furnace depends largely upon the property of insulators that long wave-length electromagnetic radiation passes through any heat insulator without hindrance into the mass, while short wave-length heat radiations escapes from the mass with difficulty. Because of this, heat accumulates in the mass and extremely high temperatures may be obtained.

6. All molten conducting matter when acted on inductively automatically stirs. In the high-frequency crucible-form of induction furnace the stirring takes place in a unique way. Thus when alloys are melted the constituents mix thoroughly.

7. Inductively heated matter when molten is a mass having a uniform temperature throughout, hence volatile constituents of alloys are not expelled at hot spots as in arc furnaces.

8. The speed at which the temperature may be raised throughout a mass by inductive heating may be increased almost without limit, because the rate of flow of energy into a mass is independent of the production of a temperature gradient from without inward.

9. In all inductive heating the temperature gradient is from the mass heated outward. Hence in ironless inductive heating the melt or molten bath is always the hottest part of the furnace.

10. Since no material substance (as vapor from an arc) enters or leaves the mass heated—energy only flowing—the means is here offered of obtaining throughout a mass of large volume an extremely high temperature without any chemical contamination of the product heated.

The result of these characteristics is expressed by the distribution of the existing installations as follows: (a) Non-ferrous industries 1500 K.W., ferrous industry (carbon free and other high grade ferrous alloys) 1200 K. W., and about 1300 K. W. for miscellaneous high temperature experimental work and melting precious metals. The American Brass Company at its various plants has the greatest number of installations.

In a paper on Inductive Heating presented before the Franklin Institute in December, 1925, Dr. E. F. Northrup says:

"Since the field of application is conceivably very extensive, only the merest outline can here be given of the suggested commercial uses to which this method of heating may be put.

(1) "Melting of the non-ferrous metals and alloys of industry, such as brasses, bronzes, pure aluminum, pure aluminum alloys, pure silver, pure copper, nickel-silver and resistance alloys.

(2) "In the ferrous field pure carbon-free electrolytic nickel and iron, singly or alloyed, and high-grade steels as magnet steels, tool steels and stellite.

(3) "An application of which little use has thus far been made but which promises to have a future is the heating without melting of steel for forging, rolling, etc., when in the form of steel rods and billets, steel pipe, etc., in those cases where the diameters are sufficient to make a frequency of 2000 cycles or less applicable (above approximately 4 1-4 inches in diameter).

"The above commercial field may be covered with current supplied by alternators of sizes and giving frequencies as follows: For the non-ferrous field 480 cycles obtained from units rated at 50 to 600 K.W. In the ferrous field 1800 cycles would be chosen as the frequency for machines up to a capacity of about 150 K.W., and for machines of greater K.W. rating 960 or 480 cycles would suffice."

In closing Dr. Northrup predicts that future developments will depend on the following fundamentals:

(1) The melting efficiency of furnaces increases rather than decreases with size and no limitation is in sight for the size of furnace which may be practically made and used.

(2) Generators of the necessary current can be built in as large units as may be required and their cost per K.W. rating falls off with their increase in size.

(3) The crucible type of furnace is restored to electric melting which makes the high-frequency inductive method the friend of the crucible manufacturer.

(4) The efficiency of melting by ironless induction compares very favorably with the best electric furnaces of other types.

(5) For the first time in the history of fuel or electric melting of ferrous materials does it become possible and feasible to melt large quantities of metal in crucibles and without the presence of any carbon and with perfect control of chemical composition and speed of melting.

(6) The circuit which supplies the high-frequency power operates at substantially unity power factor and the load on the motor which drives the generator is very steady, of high or unity power factor and is in all respects the ideal load from the viewpoint of the station man.

(7) The reactive component of the power is taken care of with condensers which, in the way used, are inherently less costly than generators made of sufficient size to accomplish the same purpose.

Statement by the American Brass Company:

We have in continuous operation 130 induction furnaces which we find to be eminently satisfactory for melting our standard mixtures containing less than 75 per cent copper.

These furnaces designed to melt our standard charge of 630 pounds normally stand in a pit to permit charging and skimming from the casting floor, and are equipped with hooks by which they are lifted from the charging pit, carried to the molds and tilted

about an axis approximately in line with the pouring spout by special overhead cranes designed for this purpose. The metal is poured into hinged iron molds through runner boxes or strainers designed to regulate and distribute the flow, the molds being carefully cleaned, temperatured and dressed between each pouring. As the molds are comparatively small, holding an average of 90 lbs., the pouring operation is necessarily somewhat slow, and in standard practice, we secure 18 to 20 heats per 24-hour day. Each furnace is served by one operator who charges, pours and prepares his own molds, and three men each working an 8-hour shift divide a bonus paid for all heats above 18 per 24-hour day. The power consumption varies considerably with the copper contents of the metal and the amount of superheat desired, but in actual practice will average 240 K.W. per ton, this figure including stand-by losses of approximately 10 per cent. A great many experiments have been made to determine the best material for lining these furnaces as a result of which we have practically standardized on the use of Chrome Ore, and with furnaces so lined, we will secure an average of 25,000 heats per lining when used for mixtures containing less than 75 per cent copper. With mixtures containing more than 75 per cent copper or containing any appreciable amount of nickel, the life of linings is very uncertain and generally so short as to make the use of this type of furnace unsatisfactory for such mixtures.

For the melting of mixtures containing more than 75 per cent copper and nickel we have during the past year developed in co-operation with the Ajax Electrothermic Corporation, Trenton, N. J., a furnace in which a standard crucible surrounded by an edgewise wound copper coil is mounted in a wooden box of similar outline to our Wyatt furnace and capable of being lifted and poured by the same cranes. In this furnace the metal is melted by induction caused by passing a single phase, 480 cycle, 1870 volt, current through the surrounding coil, the necessary power factor correction being obtained by a bank of capacitors in parallel with each furnace.

These furnaces of which we now have one battery of twelve in operation have not been in service sufficiently long to show definite comparable cost of operation, but tests made to date would indicate an efficiency equal to any other type, and an ability to melt and mix thoroughly any metal with a very low cost of crucibles, the average life of which we have found to be approximately 100, 630-lb. heats with frequent examples showing better than 100,000 pounds.

RESISTANCE FURNACES (HIGH TEMPERATURE APPLICATIONS)

Heating Furnaces For Forgings and Castings

The types of furnaces covered by this classification include the high temperature hardening, carbonizing, annealing and other forms of heat treatment.

The application of electricity to the heating of such furnaces must result in an economy of operation, if it is to be successful. But in order that the various sources of economy may receive the proper consideration from any one considering such an installation, the following list of points are taken from statements made by users of the equipment. Due to the differential, usually in favor of liquid or gaseous fuel as against electricity, the amount of gain to be derived from secondary sources usually determines whether an installation will be an economic success or not. The following are the points of advantage as experienced by users of such electrically heated equipment:

1. Repairs are less due to the linings not being subjected to excessive temperatures.
2. Operating labor less per ton than in the case of solid fuel.
3. Time required for heating furnace up to working temperature is less.
4. Rejections less, in some cases this statement is not true.
5. Product more uniform due to more accurate control of temperature.
6. Construction more adaptable to automatic operation.
7. Increased electric load factor makes cheaper electric power costs.
8. Furnaces used at off hours given power at low price.
9. Cost of current less than cost of solid fuel. In a great many cases the actual fuel costs are found to be less with oil or gas than with electricity.
10. Scaling and decarbonizing may take place if great care is not exercised.
11. The comfort of the operators is much greater, where no fumes are experienced.

Statement by Van Dorn Iron Works:

The advantages of using electric resistance furnaces for hardening and carbonizing is well exemplified by the development of the Van Dorn Iron Works Co., of Cleveland, Ohio. The plant is equipped with four high temperature resistance furnaces used for heat treating, hardening and carbonizing. The first furnace was placed in operation in January, 1922, and the results obtained caused a second installation to be made in December, 1922, followed by two more installations in July, 1923.

The furnaces are box type, double ended and equipped with unmuffled metallic resistor elements mounted on the side walls. The temperature is controlled by a recording controlling instrument.

In the electric carbonizing furnaces it was found that such a slight amount of scaling occurred on the original heavy cast carbonizing boxes that these were replaced with sheet metal boxes, thereby allowing a greater amount of product to be treated in a given time. The schedule of the furnaces was worked out to insure a maximum operation with a minimum time in which the furnaces could cool down.

The addition to the electric power load from these furnaces helped enormously in improving the power factor. Prior to the installation of the furnaces the intermittent operation of the few induction motors in the shop resulted in a power factor of .55 which was brought up to .95 when the furnaces were added. With electric power companies giving credit for high power factor the results obtained, especially with 24 hours a day operation, would allow a very good purchased power rate.

The economies indicated by the first furnace installed which resulted in the installation of the other three furnaces have been amply proven. The repairs

to an electric furnace are much less than on a coke, gas or oil fired furnace. The linings are not subjected to excessive temperatures and therefore last indefinitely.

The labor charge per ton in the electric furnace is less than that of the coke furnace with was previously used. The time required to bring an electric furnace up to heat is considerably less than that required for the coke furnace and the cost of current is far less than the cost of coke. The amount of rejection has been reduced to practically nothing as the control instrument keeps the temperature within close limits and allows a duplication of results to be obtained which was impossible with the fuel fired equipment.

Statement by Wyman-Gordon Company:

The reason our company has installed electric furnaces for heat treating forgings is, that it enables us to adopt a type of furnace which lends itself to the automatic operation on our type of product.

This type of furnace is such that it would be impossible to heat it in any other way and secure continuous operation without costly maintenance delays. The selection of this type of furnace is an advantage, in that it enables us to greatly increase our production per square foot of floor area taken up, which in our particular plant is a decided advantage. From a cost standpoint, our estimates do not show that there is going to be any saving. This is entirely due to the differential on cost of power as compared to cost of oil. These large furnaces have not as yet gone into production, and for that reason we cannot state whether or not they will materially beat our estimates.

Statement by the Tool Steel Gear and Pinion Co.:

We installed the large twin chamber furnace of the resistance type nearly three years ago in order to test out the possibility of this type of heating under our own particular operating conditions. At that time, and probably even now, the principal development and application of this method of heating seemed to be in the automotive industry where the parts to be treated are generally small and handled in large quantities, while our work is all much larger and heavier, with practically no uniformity in size and shape so that our problem is quite different. We could therefore get no comparative data as to the advantages or disadvantages of this electrical heating as applied to our own particular conditions and consequently decided to test the matter out by installing one furnace in our own plant.

We are sorry to say that this experiment has not worked out satisfactorily from an economic or cost standpoint as we find the cost per pound of material treated to be a great deal higher than with our oil fired furnaces, and have not been able to discover any material advantages to offset this in the way of improved quality of work, freedom from scaling etc.

Statement by Frost Gear and Forge Company:

We are using two electrically heated furnaces with rotary tables in the belief that they give us a greater uniformity of product.

That they are continuous in operation we believe speeds up production over the old way of heating in a lead pot. We do, however, have to be very careful about the matter of scale, which is greater than when heating in lead.

Another item to be considered is the comfort of the men. The electric furnace of course is far more desirable in this respect.

One disadvantage that we find is, in heating in the electrical furnace, there is decarbonization of about four points more than in the lead.

The simplicity of control is another advantage in the electrical furnace over the hand operated oil burners, and we believe that this would also apply to automatically controlled oil burners.

Statement by Canadian General Electric Company, Limited:

The Davenport Works of the Canadian General Electric Company have connected to their system 700 K.W. of electric heating, covering annealing furnaces, baking ovens, soldering pots, blue print driers, etc.

Their preference for electric heating in these cases is because as applied, it is more economical than other forms of heat. Some of it is used at night on a special price basis. It has greater ease of application, definite heat control and safety in operation, all of which tend to produce more uniform product. In addition, of course, there are no fumes or mess as compared with other forms of fuel.

Statement by Whitin Machine Works:

We are using six electrically heated box type furnaces for annealing and carbonizing our work.

We anneal about 11 tons of cast iron on an all night run and during the day these furnaces are used for carbonizing and heat treating. These furnaces have been in operation now night and day for nearly three years and we are having most excellent results with them and they are saving us some money over and above our old methods of annealing and heat-treating with coal and oil.

We are also about to install an electrically heated lead pot for doing some of our hardening of high carbon steels.

Statement by the General Electric Company:

The car bottom electric furnace of Fig. 3 is used at Schenectady for annealing plates and small and moderate size steel castings, at temperatures around

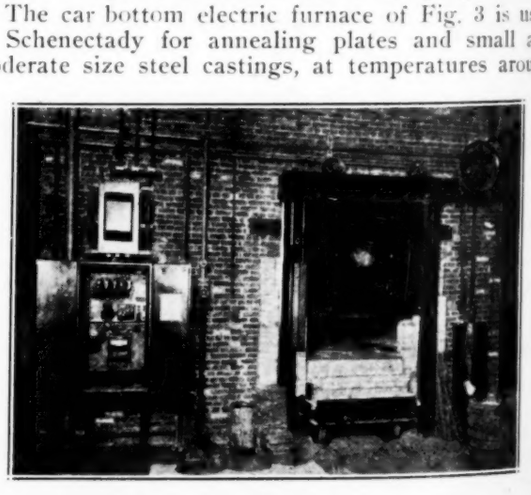


FIG. 3

1562 deg. F. The heating chamber dimensions are: Length, 6 ft.; width, 4 ft.; height, 3 ft. 2 in. This furnace is operated only at night, usually starting at 10 P. M. and running from 10 to 12 hours. At the end of the heating period the charge is removed from

the furnace and allowed to cool in the indoor air. No attendance during the night is required.

The space factor is important in the economy of annealing furnaces, particularly where castings are annealed. Castings vary so widely in their weight volume relation that a heating chamber may be completely filled with a comparatively small weight of hollow castings, or on the other hand not half full with several times that weight. The heat loss through the walls while the furnace is hot is constant, without regard to the content of the furnace, and the less the weight of the charge the greater this loss per pound of material. The same is true as regards the heat

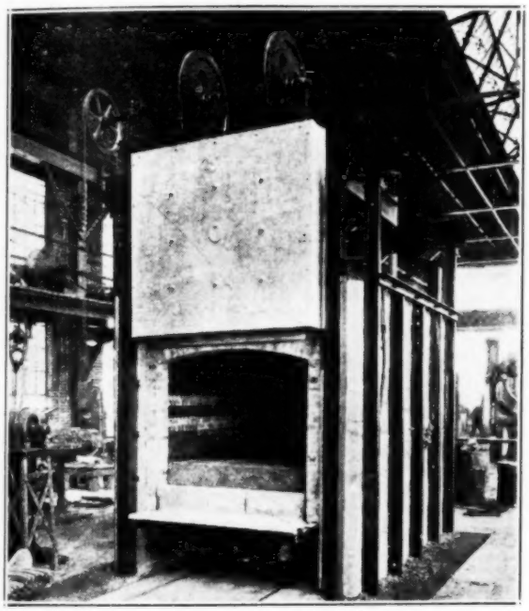


FIG. 4.

stored in the walls, car, supports, etc., which is lost with each cooling.

The furnace of Fig. 2 takes work as it comes and the weights of the daily charges vary from 2500 to 6500 pounds. The heating cycles are fairly uniform and the following tabulation of averages for a period of eight months illustrates the influence of space factor on pounds per kilowatt hour for this furnace:

Weight of Charge	Lbs. per Kilowatt Hour
2000	2.0
3000	2.5
4000	3.0
5000	3.5
6000	4.2
6500	4.5

This furnace has been in continuous operation for two years and so far has cost practically nothing for repairs.

The service of the furnace shown in Fig. 4 is annealing high speed steel and steel forgings, the material being cooled in the furnace. A temperature of 1427° F. (775° C.) is used. The charge is stacked on open supports, about 7 inches above the car floor. Only side wall resistors are used. The rate of heating is slow, approximately 12 hours being taken to reach the final temperature as measured by a thermocouple placed near the center of the charge. This is followed by a "soaking" period, usually about 4 hours, after which the power is shut off and the charge allowed to cool in place to about room temperature. This is a type of slow cooling furnace, a large part of the energy input of the heat cycle being stored in the walls and car bottom and utilized for controlling the rate of cooling of the charge.

A typical run of this furnace for which the charge was 14 pieces, total weight 7905 lbs., required 2820 kilowatt hours. The space factor was 10%. The labor charge was $1.05, attendance charge $1.00.

Statement by Dodge Brothers:

The major portion of Dodge Brothers', Inc., Electrical Heating is confined to the heat treating of steel although we do considerable electric welding, both for spot and arc.

We will enumerate briefly the reasons for the rapid increase in the use of Electrical Heating as applied to heat treatment of steel at this plant:—

1. Absolute control of heating input and direct application of this heat to the steel.
2. Flexible heat control—the charge end of furnaces may be carried at higher temperatures, thereby decreasing the time cycle of the heat treating operation.
3. Low maintenance cost.
4. Better working conditions, lack of smoke and less heat radiated from the furnaces.
5. Better assurance of future supply and present source of fuel.
6. Low heat loss due to heavy insulation and lack of flues.
7. Decreased labor cost.

As a result, we obtain the highest quality of work in face of high production at minimum cost and at a considerable saving in floor space.

We are not in a position to give you a great deal of information on welding but these operations have been in use a great deal longer than the heat treating processes and more accurate cost figures are available in the industry as a whole.

Over a period of two years and a half, our net cost for fuel on continuous Electric Carburizing of steel has been under $.006 per pound. This is based on an average carburizing time of fifteen hours in the furnace.

HEAT TREATING FURNACES FOR TOOL ROOMS

The small furnace, resistance type, is finding a considerable number of applications in tool rooms for heat treating purposes throughout the steel and other industries. Especially when equipped with certain special types of control it is admirably adapted to this service. The question of cost of fuel for these small furnaces is usually only a secondary consideration for quality of product and ability to duplicate results is of prime importance.

The application of such furnaces to the pipe and tube industry for the treatment of threading tools and piercing points is only one of a great number of installations.

Statement by Gary Tube Company:

We are using electric furnaces to a limited extent for heat treating threading tools and piercing points, for which purpose we have found them preferable to furnaces of other types for the following reasons:

A—Better temperature control.

B—Uniformity of temperature.

C—Less scale formation.

Statement by a Gear Manufacturer:

"A Hump furnace is used in this plant for carbonizing the product. A double heat treatment or quenching is required, one for the core and the other for the case. The strength of the material is largely influenced by the proper refinement or heat treatment of the soft center or core and we have found that the Hump furnace enables us to secure the maximum physical properties from the material being treated with a greater degree of regularity or uniformity.

"It is readily apparent that when material is heated in an ordinary furnace whether electric or fuel fired, the temperature recorded by the usual pyrometer simply indicates the furnace temperature at the particular points where the pyrometer may be placed; therefore the proper temperature from which the work must be quenched and the length of time which it should soak at that temperature in the furnace are to a considerable extent a matter of judgment, especially where the furnace loads vary considerably in size, shape and weight. Consequently it is much more difficult to closely duplicate results assured from such ordinary furnaces.

"Another big advantage of the Hump furnace is that in its operation, errors in the thermo-couple do not make any difference because you are working largely from the critical point of the material, as indicated on the temperature curve chart by a break in the curve, regardless of the actual temperature at which this occurs. When working from actual temperatures as indicated by the pyrometer in an ordinary furnace it is necessary that the thermo-couple be accurately calibrated and checked carefully from time to time in order to be sure of its accuracy.

"About the only drawback to the greater use of Hump furnaces in our plant is their comparatively small size, the largest size made at the present time being only twenty-four inches in diameter.

"The average load in the Hump furnace is probably about 400 pounds. The average of a number of test heats which we ran to temperature varying somewhere between 1450° F and 1700° F. showed 10.2 pounds treated per KW hour.

Statement by the General Electric Company:

The electric furnaces of the tool and die shop of Building 17 at Schenectady, shown in Fig. 5, have appeared in print more than once. Their continuous service without a shutdown since the date of installation, August 1919, entitles them to a certain amount of respect in the comparatively young life of the electric furnace industry. The service is the heat treatment of tools and dies, plain carbon and carbon-chrome steels.

The heating chamber dimensions are: length 42 inches, width 36 inches, height 30 inches. The connected load of each furnace is 20 KW. Operating temperatures: Left hand furnace, 1472° F. (800° C.) Right hand furnace, 1112° F. (600° C.) The flow of work is intermittent. Quality of the product is the one essential requirement. The cost of the heat units is a cent or two a pound. The value of the product is many dollars per pound.

These furnaces have averaged around 50,000 pounds of heat treated steel per annum for several years. Up to the present time the only repair work needed for these furnaces has been an occasional repair to the brick hearths, which wear due to the sliding of the charges in and out of the furnaces.

In dealing with furnace problems one cannot, with wisdom, overlook the viewpoint of the operators. The

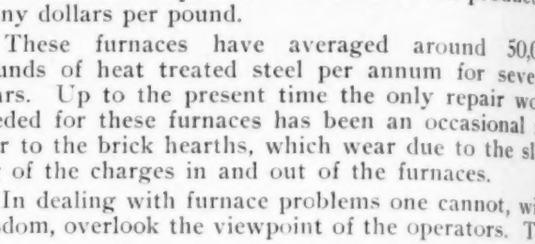


FIG. 5.

comment of the foreman of this shop regarding his men is: "These men have had a nice, clean, comfortable job so long, and get their work out with so little trouble, that if we were to go back to the old fuel fired furnaces I believe they would quit the job."

ELECTRIC HOT TOPS FOR MOULDS

During the current year the use of the electrically heated top for ingot moulds as practiced by the International Nickel Company at Huntington, West Virginia, was covered by a paper given by Mr. F. C. Watson, Electrical Superintendent of that company and published in the February, 1926, issue of the Iron and Steel Engineer, a brief resume follows:—

The nickel and monel ingots are cast in moulds 14x14 inches at the top and by 11x11 inches at the bottom. A refractory hot top having a hole in the cover is placed on the top of the mould, the electrode being introduced through the hole in the cover. The metal is poured to a height of six inches above the top of the mould, the truck carrying the electrode and automatic control equipment is brought into position and the electrode lowered into the hot top. The electric current used in the production of the electric arc is obtained from one phase of a three-phase supply. The neutral is connected to the track supporting the mould car. After the arc has been on from 1½ to 2½ minutes at 3000 amperes, the current is reduced to 300 to 400 amperes and maintained for 2½ to 3½ minutes. The voltage from phase to neutral, with 3000 amperes flowing and only one electrode in use, is approximately 100 volts.

After the arc has been on for a total of 4 to 5 minutes the electrode is withdrawn, the hole in the hot top cover is closed and the electrode truck moved to another ingot. A 3-inch graphite electrode is in use, being adapted from a half ton furnace. The electrode consumption amounts to ¼-inch per heat.

The results obtained by the use of the electric arc on the ingot head have been very satisfactory. In 85% of the ingots to which the arc was applied no pipes were formed. The practice prior to the use of the electric hot top consisted of casting an 18-inch extension to the ingot for absorbing the pipe. This was afterward sawed off. No sawing has been necessary with the new practice. The practice with nickel or monel ingots is not entirely comparable with steel ingots due primarily to the segregating tendencies of the metalloids in steel. However the possibility of the production of sound ingots or castings by such a method without the use of sink heads offers possibilities. The method is being tried in connection with the steel industry at present.

ROLL HEATERS

Manufacturer's Statement:

Like a certain well-known automobile, the electric roll heater has been constantly improved, but there have been no radical changes in the design. To some extent the improvements have been calculated to better the performance, but to a greater degree they have been such as to facilitate handling and adjustment and to render the equipment more rugged and foolproof.

The principle of heating by conduction through contact of the heating elements upon the rolls is, in our opinion, definitely proven as correct both for the most efficient heating and also to secure the definite heat distribution which is peculiar to the electric heating method.

To facilitate easy and accurate fitting of the heaters to rolls of varying diameters, the proper contour of the heater sectors has been determined and is being closely maintained in construction. For like purposes, material improvements have been made in all the adjusting devices and they have been made more rigid. Strength has been added at several points definitely to prevent distortion either from heat or usage.

Electrically, the heaters have been improved principally by the adoption of non-scaling chrome-alloy sheathed heating elements and by the provision of a totally enclosing housing over the end connections. A better method of mounting the heating elements to permit expansion has been adopted.

The largest electric roll heater yet built was furnished to the Tennessee Coal, Iron & Railroad Company for the new sheet mill at Fairfield. This heater, adapted for use on rolls of 32-inch diamter and 72-inch width, consumes nearly 100 KW.

A somewhat new application of the electric roll heater has been made by the American Nickel Corporation. Operating a sheet mill on a single turn basis, the electric roll heater is applied daily to maintain the roll temperature between turns.

Electric roll heaters have now been applied to mills rolling common and full finished sheets and in plate. The method has demonstrated its applicability to each class of service.

Statement by the Standard Tin Plate Company:

In February, 1925, we purchased one electric roll heater twenty-four inches wide. We used this on various mills with rolls thirty inches wide to thirty-four inches wide. The results were entirely satisfactory on thirty-inch rolls, as we could start immediately to roll thirty gauge on the width for which the mill was turned. On our thirty-four inch wide mills we found the heat distribution not quite so good and we had to roll perhaps twenty pairs of twenty-five inches wide before we could go on to thirty inches wide, thirty gauge.

Early in July we had two more roll heaters shipped to us, one being twenty-seven inches wide and one thirty inches wide. The object was to try both widths on our thirty-four inch wide mills. We found that the twenty-seven inch width heater was just right, putting the rolls in shape to start off with thirty or thirty-one gauge and thirty inch wide orders. The thirty inch wide heater gave a little too much heat near the ends of the roll and on the necks. We kept the twenty-seven inch wide heater and returned the thirty inch wide heater.

We continued to use these two heaters regularly for several months, recording the performances of the mills on which they were used. The electrically preheated mills regularly produced about four thousand pounds more on the first turn than our other mills and the scrap loss was six to eight per cent less on the preheated mills than on the others.

Our only case of trouble was the burnout of a terminal on one heating element. This caused no damage.

As a result of the performance of these two electric roll heaters and because of the savings they have demonstrated, we have placed an order for twenty more twenty-seven inch wide heaters and two more twenty-four inch wide heaters, which, with the two now in service, will fully equip our mill.

I might add that we also use the heaters to warm up rolls before a change during the week. They work out all right for this purpose.

Statement by the Central Steel Company:

In a plant of 14 mills, a complete installation of electric roll heaters was made, consisting of eight 28-inch diameter by 30-inch face, five 28-inch diameter by 36-inch face, and one 28-inch diameter by 44-inch

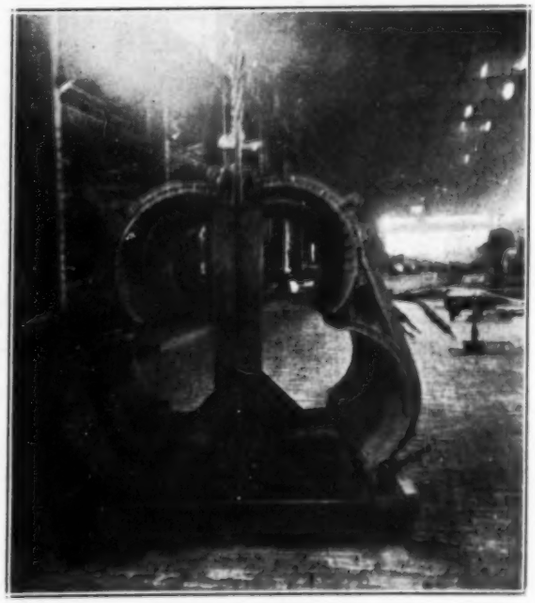


FIG. 6.

face heaters. This installation was completed September 15th, 1924.

Prior to this the heating was done by natural gas, which required the mills to be turned over during the heating period, usually lasting about 8 hours. About 20000 cu. ft. of gas, at 60c per 1000 cu. ft., was required for each start-up. The friction load on the mills runs about 275 K W for each train of seven mills each.. Accordingly, for each start-up, 2x275 K. W. by 8 hours —4400 KWH—was required for turning the mills. With this method, the temperature attained by the rolls was only about 175° F, so that the mills were not in good rolling condition for the start-up. Therefore, almost the entire output of the first turn was required to warm up the rolls to the proper temperature.

With the electric roll heaters, terperatures of 525 to 600° F, at the middle of the rolls, and 325 to 375° F at the end of the rolls, are obtained. This corresponds to the temperature of rolls in good working condition, and makes it possible for the first turn to start rolling first class sheets.

The power consumption of the heaters runs as follows:

30-inch	48 KW
36-inch	56 KW
44-inch	72 KW

The heaters are usually connected first in series for about 2 hours, to give a slow heating, then in parallel for about 11 hours. This schedule of operation can be varied to suit the results desired, prevailing weather conditions, character and condition of rolls, etc. The power consumed for one start-up runs 8000 to 8500 KWH.

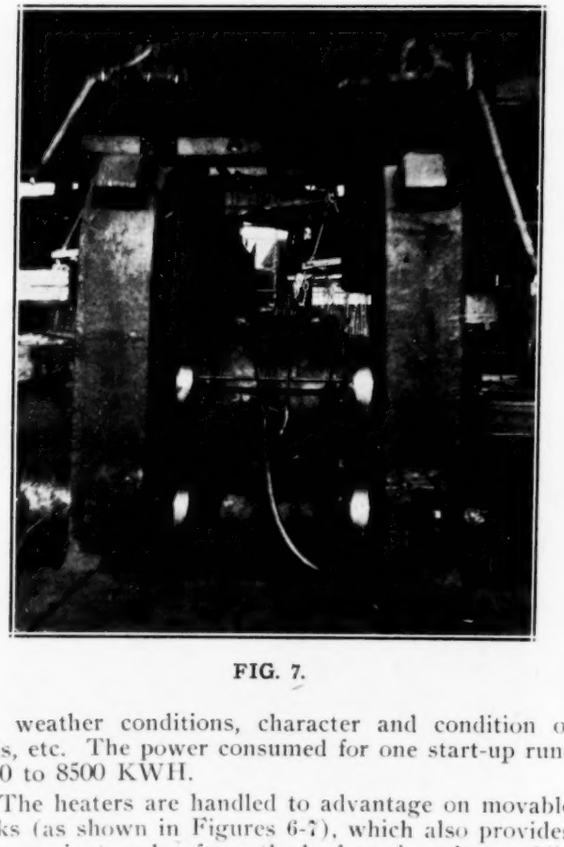


FIG. 7.

The heaters are handled to advantage on movable racks (as shown in Figures 6-7), which also provides a convenient and safe method of storing them while not in use. Each rack holds three heaters, and can be carried by the cranes to convenient points along the mill. When the heaters are removed from the mills, they are swung directly to the racks by the crane, and held there by engaging the upper clamp bolt of the heaters. These racks can then be carried by the crane to convenient places for storage, and rolled on their own wheels under the lean-to. This method of handling greatly facilitates the use of the heaters, only 17 minutes being required to clear the entire 14 mills, so that the delay from this source is negligible.

Spare rolls are also kept hot through the week in these heaters, so that if a roll change should be necessary through the week, the newly installed roll is in shape to roll first-class sheets immediately. The heating of spare rolls in this plant uses 42,000 KWH per month.

The maintenance cost on these heaters is very low, and practically no repairs are required. The life of the heating elements is excellent, replacements so far running less than 1% in the year and one-half of operation.

There is no doubt as to the advantages of having the rolls in good condition. They may be summed up as follows:

1. Saving in warming-up iron. These sheets are somewhat difficult to dispose of, and entail a considerable loss in putting them in shape for the market.

2. Greater production of finished sheets. On starting, maximum production is possible almost immediately.

3. Less scrap loss on the starting turn, due to better shaped sheets.

4. Increased life of rolls. The uniform rate of heating eliminates stresses within the rolls, and the method of heating does away with the shocks during the warming up period. This results in decreased roll breakage.

These results are actually obtained in practice with these heaters, and everyone is very enthusiastic over their performance.

LOW TEMPERATURE APPLICATIONS

The application of resistance type electric heating to low temperature work is wide and various. New uses for such heating are appearing from time to time, and especially in plants which are considering complete electrification, applications of electric heating are considered which would not be economically sound, except in their relation to the whole scheme. Under such headings can be mentioned the production of process steam at distant points by using immersion heaters, the heating of small outlying office buildings, shops, etc. In other cases where the differential between electric heat and other fuels is not too great, the added advantages derived from the application of electric heat to certain processes show a gain from electrification.

ELECTRICALLY HEATED TIN POTS

Statement by Bethlehem Steel Company:

At the Maryland Plant of this Company an installation was made on an electrically heated tin pot. On the tin side, 100 KW of heating units were installed, of which 75 KW were automotically controlled. In the beginning 25 KW capacity of heating units were installed on the palm oil side but it was found later that their use was unnecessary except for a short time for starting the pot. The operation of the tin

heating units is controlled by thermostats and when the pot is under comparatively low production this operation is quite regular. However, the production has increased so much that the limit of the heaters in the pot has been reached and the automatic part of the control does not function as often as it should in order to maintain the temperature required. The installation was made late in December, 1925, and the operating results so far indicate that from a tinning standpoint the results are better than with gas fired pots. The production has been increased about 50% per pot and the sum of the other factors entering into operation have been reduced materially, so that the additional cost of electric heat over gas has been offset, showing slight savings in favor of the electric pot. The success of the installation will depend to a great extent on the relative costs of electric power and gas.

WIRE DRYING AND ANNEALING

The application of electric heating to furnaces for drying and annealing wire and similar products is growing in favor. One such installation is used for drying acid from rods before drawing at the National Screw & Tack Co., Cleveland. Natural gas had been used previously as fuel. The electric heated furnaces were found to have much greater capacity, three electric ovens replacing seven gas fired ones. The ovens can be brought up to the desired temperature in about one-tenth the time while the period required for drying has been reduced from one and a quarter to and and a half hours to 10 to 20 minutes. The increase in rate of drying was attributed to the absence of the moisture formed by the burning gas. The capacity of the ovens has increased from 1.5 tons per hour to 5.5 tons per hour per oven. A secondary advantage obtained was the elimination of a glazed coat left on the rods dried in the gas furnace. The coating scratched the rods and clogged the dies, and its elimination in the electrically heated oven has resulted in longer life for the dies. The cost of electric heat is greater than for gas but the increased tonnage has resulted in a lower cost per ton.

An installation has been made at the Worcester Plant of the American Steel and Wire Company for the continuous hardening and tempering of steel wire. Two small electric furnaces have been installed. They are lead pot furnaces and are simply an adaptation of electric heat to the previously oil fired furnaces. The furnaces have been in operation such a short time that a statement concerning their operation could not be obtained.

A somewhat similar operation is being accomplished by the Columbia Steel Company at Elyria, Ohia, where strip steel is being continuously annealed through electric heating. The application should really be considered under high temperature installations as a temperature of 1850° F is maintained and the new process displaces the older type of box annealing. Metallic resistors are employed as heating units and the consumption of power is approximately 175 to 200 KWH per ton.

A new development in electrically heated furnaces is the continuous furnace for normalizing. There are a number of these furnaces to be installed in the near future and data regarding their operation will be included in future reports of this Committee.

Another installation in the wire industry is covered by the following description:

An installation of electrically heated furnaces for the continuous hardening and drawing of high carbon steel wire has been may by Westinghouse E. & M. Company.

The wire to be hardened is fed from spools and a multiplicity of strands is passed through a furnace chamber about 18 feet long, and from thence through a granulated coke protection screen to a lead hardening bath. Without interruption, the strands are then carried through a drawing furnace of the lead bath type maintained at proper drawing temperature. As the strands leave the drawing bath, they are wiped free of any adhering lead and are fed onto a reel. The entire operation is automatic with the wire traveling at rates varying from 40 to 60 feet per minute.

The heating chamber of the hardening furnace consists of a tunnel of nickelchromium heat resisting alloy with a cross-sectional area about 12 inches by 1 inch. Heating elements are mounted above and below this tunnel. The furnace is sectionalized into 3 heating zones each of which is individually controlled. The coke screen closes the exit end of this furnace and this coupled with the fact that the entering wire is covered with a slight film of grease renders the furnace atmosphere practically non-oxidizing.

The lead quenching bath is equipped with means for heating, but this is largely to permit melting the lead when starting up. When under production the continuous quenching of wire is about sufficient to maintain the lead in a molted state.

The lead drawing bath is electrically heated and automatically controlled. Temperatures ranging from 700 to 1200° F. can be steadily maintained so that a wire with various physical properties can be produced.

The equipment is capable of hardening and drawing up 225 pounds of wire per hour.

GALVANIZING KETTLES

An interesting application of electric heat equipment to a galvanizing kettle was placed in successful operation early in 1925. As far as is known this is the only electric galvanizing kettle in existence.

The kettle is a V-shaped trough made of 1¼-inch steel with welded vertical ends. The top is flanged over for 12 inches all around, to provide a warming and drying surface for work to be galvanized. The capacity of the kettle is approximately 23 cu. ft. of melted zinc. The kettle is supported and enclosed by walls of Sil-o-cel and fire brick, and is supported by 3 fire brick pedestals properly shaped. The heating units, 4 in number, are divided 2 units to either side. Portable covers of steel plates and brick are put on the kettle when it is not in use.

The electrical equipment consists of 4 heaters, a thermostat for control or temperature and a control panel operated by the thermostat. The heaters are each rated 20 KW on 110 volts and they are connected 2 in series across 2 phases of a 3-phane, 220-volt, 60-cycle line. The thermostat control is set to hold the kettle between 800 and 850° F while operating and at lower temperature while idle. The temperature control has proven entirely satisfactory.

The operators of this kettle report that in comparison to the previously used coke kettle, the operation is cheaper and drossing is reduced to a negligible amount. The production is increased, working con-

ditions are cleaner and because of the automatic control no attention is required.

BABBITT POTS

One class of repair work which often causes trouble in a steel mill is the rebabbitting of bearings. The class of labor often employed in this work is not of the best so that accurate control of gas fired furnaces is not obtained. The results under such circumstances can hardly be much better than they are. The installation of electric heated pots at one steel mill has been proven economical and very satisfactory. Much better product and much greater capacity being obtained from the same crew of men with no increase in fuel bill.

Statement by Westinghouse Electric and Manufacturing Company:

In one shop four-1500-lb. soft melting pots are used on large railway motor bearings and axle shaft shells. Each pot is controlled by a pyrometer, set according to the particular composition being poured. One pot is used only for tinning purposes. Tin-base babbitt is for the most part used on railway bearings because of the severe service conditions.

This installation has been in practically continuous operation since September 1924, and has been shown to many visitors interested in this particular class of work. The operators are very pleased since changing from gas-fired pots. They give the reasons as:—better working conditions through lack of fumes and lower temperature radiated from the pots, as well as marked improvement in the quality and texture of the bearings produced, because the temperature is controlled within a few degrees of the correct pouring temperature for the alloy. The watchman starts the pots at five o'clock in the morning, which permits to pots to be up to the correct temperature by seven o'clock. The total installed capacity is 100 KW operating at 220 volts.

ELECTRIC ARC WELDING IN THE STEEL INDUSTRY

Statement by Mid-American Welding Engineering Company:

In the steel industry as in no other industry, there are tremendous overload conditions usually inavoidable that cause breakdowns in vital working parts of the mill. The general working condition of the machinery is worse than most all other industries for heat burns out lubrications and dust and scale gets in bearings and moving parts, making these parts wear out much faster than they should.

The fact that the larger percentage of investment of the steel mill lies in its machinery, and that the cost of upkeep on this machinery has been practically the same as renewing it every three years, make engineers keep looking for every turn in the scientific field, for help in removing friction, increasing life of metals, and repairing the parts that are unavoidably worn out and broken.

Only a short time ago the work of the electric arc welding was looked upon as a wonderful new development, but it is very common. In fact, so common that few steel plant managers fully appreciate what real scientific guidance welding departments need to get the greatest good from them.

Arc welding had progressed considerably before it was an assured fact that overhead welding could be done with the same degree of efficiency of weld as horizontal welding was being done.

Naturally the plants whose welding was guided by someone alert to the progress of the art of welding were the first to receive the benefit of savings being made by repairs in place. Likewise when an electric welding foreman devised methods of building up fast-wearing surfaces of high carbon and high manganese material by rod coating methods, the plant for which such welding leader worked had the benefit of many wearing parts lasting much longer than competitors' parts were lasting, thus deriving a distinct benefit from that development.

Consider what it means in quality production to have a "hot mill" accurately lined up. It is not possible if the brass seats and rider bearing surfaces are worn out of standard. The electric arc today is replacing the few pounds of metal that has worn off of housings of all sizes, thus not only salvaging the housings but keeping it in shape to do its work accurately.

Building up worn wobbler pods on spindles, rolls, pinions and boxes with high carbon and high manganese rods has been proven to make the part last no less than three times as long as the original new unwelded pod.

The electric arc welding provides a satisfactory means of welding without pre-heating, and in many cases removal of parts made of grey iron. Work which has been done in this direction includes blowing engine cylinders which have cracked in service, large gas engine cylinders which operate on blast furnace or producer gas, crane engine cylinders, locomotive engine cylinders, pump cylinders, steam separators and steam traps. The saving in work done by the electric arc welding process on material of this kind is usually very large. Spare castings are usually not carried for parts of this nature, and a delay of a week to six weeks occurs between the time the casting is ordered and the time it arrives on the job. In many cases a machining operation to get the casting ready to use also causes considerable delay.

The electric welding of flues to the back flue sheet of boilers is an important application of electric arc welding and cannot be done in any other way. This work is done only in fire-tube boilers such as are used for waste heat boilers in the open-hearth furnace, locomotive crane boilers, dinky locomotive boilers, etc. Welding fire-cracks in the fire-box of boilers for locomotives is another application of electric arc welding. In dinky locomotives, the same job frequently occurs in which fire-cracks have to be welded on short notice and the electric welding offers the quickest means of accomplishing the work.

Welding in place of caulking with the electric arc is an important application in steel plant work. Jobs of this nature are found on gas lines carrying producer gas or blast furnace gas, on blast lines, on the blast furnace shell itself and on stoves. After riveted plate construction, such as the above, has been in service awhile, the riveted joints become loose and a considerable amount of leaking results. In order to re-drive the rivets, it is necessary to practically tear down the structure. Welding on this work has been found to cost slightly less than caulking with an air gun. Another important application on the same class of equipment is in the welding of riveted joints which have failed. An example of this, which came within

the experience of the writer, was a girth seam on a blast furnace. This seam failed by shearing of the rivets while the furnace was in operation. The failure of the girth seam through an arc of about 90 degrees endangered the operation of the blast furnace, due to the fact that the whole structure above the point of failure might have come down at any time. Also, there was a possibility of shifting the blast furnace lining, due to shifting of the blast furnace shell. It would have required a shut-down of about three weeks to tear out the lining of this blast furnace and re-drive the rivets of a patch for this job. A patch put on with patch bolts would have required five to six days and the job would not have been very certain, owing to the inherent weakness of a practice of this kind. By the use of electric arc welding, butt straps were welded across the faulty girth seam by 36 hours of continuous welding. The blast furnace was not shut down at any time, and worked its full capacity during the welding operation. The welding operator ignited the gas coming out of the seam, so that he was in no danger of carbon monoxide poisoning during the welding operation. This job has been in operation three years.

Welding in place of caulking is the only way to make a riveted seam tight so that it will stay tight. The caulking does not hold the caulking edge of the seam down to the plate, whereas welding makes a positive connection between the caulking edge and the adjacent plate. This practice as applied to blast lines and gas lines results in a large saving in a comparatively short length of time.

Electric arc welding finds a wide field of usefulness in the repair of broken and worn steel castings. Under this classification comes yokes, truck frames, and trunnions and cinder ladles, hot metal ladles, ingot buggies, steel castings on gas producers and stoves, electric cranes, trucks and manipulator castings.

Electrically welded stacks for the open-hearth sheet mill and miscellaneous smoke stacks about the mill, are better and last longer than ordinary riveted stacks. Failure of a stack is due to corrosion or from the inside, due to the gases and rust from the outside due to the water. As soon as the stack begins to leak air through into the hot gases, the destruction of the stack takes place in a very short length of time, due to the combination of the water and the products of combustion in the gases. The electrio couple liberating pure oxygen causes rapid oxidization of the adjoining edges of plates in smokestacks. The riveted seam provides a ledge either on the inside or on the outside of the stack on the circumferential seams. There has to be a lap one way or the other with the riveted construction. The stack may be made with electric welding and a lap joint used, but owing to the welding on the edge, no projection or ledge is provided for accumulation of soot on the inside or accumulation of water on the outside. The seam is always tight and it is a matter of experience that the life of the completely welded stack is about twice the life of a riveted stack.

Steam lines around a steel mill are a source of considerable amount of waste and may be a cause of shutdown. The large steam lines have cast steel flanges screwed on the pipe. It is the practice of several plants within the writer's experience to electrically weld the cast steel flange to the pipe, in addition to the threading. It appears that the threaded joints eventually leak and the wire drawing of the steam and corrosive action weaken the pipe at the thread, causing waste and liability or failure of the steam line, with attendant loss of life and shut-down of the plant. This is another case of insurance against shut-down by the use of electric welding.

Every steel mill has a large number of crane motors and there is a considerable application of electric welding in building up of the bearing area of the armature shaft, the pinion seats and straightening out of keyways which have been damaged. This work falls in the electric welding field due to the economical application of metal through the electric arc. There is considerable time saving in the use of electric welding for the purpose stated above, and there is a saving due to the fact that a new shaft does not have to be machined for the job. The elimination of pressing the old shaft out and new one in by the use of electric welding is also an important item.

Repairs to dinky and standard locomotives. Large steel plants usually have locomotives for their own use. The application of electric welding to the maintenance of a locomotive is a standard job and the savings are usually well known. The main jobs are as follows: The locomotive frame may be welded with the electric arc process without dropping the wheels in most cases. This results in considerable saving of time. Locomotive cylinder welds may be made without pre-heating the cylinder or machining the cylinder after the weld has been made, using the electric arc process. Fire-box welding may be done by the electric welding process. Scored main rods may be repaired with the electric process. Cracked spokes in cast steel driving wheel centers may be welded with the electric process without removing the tire or dropping the wheels. Sharp flanges on driving wheel tires may be welded with the electric process with great saving over cost of new ones being put on.

Miscellaneous manufacturing operations using electric welding are of very great advantages many times. Operations of this kind are:—gear cases, miscellaneous tanks, galvanizing kettles, alloy pots, water-cooled skid pipes, shop trucks, storage bins, etc. There is some emergency work done under this classification where an important grey iron casting has failed in service and steel plate and structural steel arc welded together to produce a steel piece to do the same work, where grey iron castings have been used and are subject to frequent failure, this practice of reproducing the part in welded steel cures the difficulty and saves the shut-down time due to failure of the casting. New parts are manufactured for crushing apparatus. Conveyor buckets and clam shell buckets.

Electric arc welded 20-inch diamater water pipe formed of 3/16-inch plates and welded to form one piece water system for open hearth cooling purposes has been in service for eight years. A 16-inch gas line built in the same way has been in service six years, without a dollar being spent on maintenance of either one. Electric arc welding has an enormous field in this work about a steel mill.

The following are some of the miscellaneous jobs handled around a steel mill not covered in the above descriptions. These are jobs taken from the records of a steel mill having electric arc welding equipment.

Welding of bell rods for blast furnaces in which manganese steel is built on the wearing surface. This surface is worn by passage through the collar in top of the blast furnace.

Welding caulking edges of leaky riveted seams on downcomers on the blast furnaces.

Welding steel castings to adjacent plate on doors, on blast furnace stoves, welding cracks in top and bottom water pans on gas producers.

Welding cracks in steel castings on hot blast drums. This is a part of the blast furnace stove and the cracks occur from the heat expansion and contraction.

Building up rams, wheels and rails on open-hearth charging machine.

Building up bearing collars on motor housings, so that they come back to standard and take the standard bearing. This job may be done on either grey iron or steel.

Welds in the bottom of vertical crane boilers. This welding operation takes the place of the mud ring rivets on the boiler. Experience has proven that this gets away from a lot of maintenance work, due to small leaks down around the mud ring rivets.

Welding laminated edge of ladle hooks. This is a shop job and materially increases the life and safety of the ladle hook. This hook is made of laminated steel riveted together and as soon as the rivets get loose the tendency is for the laminations to come apart, and this jeopardizes the safety factor of the hooks.

Welding seats of blowing engine cylinder valves.

Welding seats of hydraulic pump cylinder valves.

A newly-developed field in arc welding is in structural work, buildings being remodeled and new buildings being built without the use of a rivet.

It has been found that many electric cranes and charging machines have required excessive maintenance due to the riveted joints of the end truck to the girders, pit cranes, stripper cranes and charging machines get such abuse that rivets soon loosen and allow the whole crane to get out of alignment; this trouble is entirely eliminated by welding the end truck housing to the girder and represents a distinct advance in maintenance of such equipment.

It is quite pleasing to note the distinct advance welding equipment manufacturers made have made in the line of stable arc equipment. The arc characteristics alone many times spell the difference between a failure and successful weld. Realizing the importance of good equipment, good materials and operators, electric arc welding is the most powerful and increasingly useful tool a maintenance superintendent has.

When properly selected, organized and instructed welding operators will do good, conscientious work and do electric arc welding justice, but let the operator be dissatisfied, untaught and trying to "get by," nothing can be hoped for. So it is, then, of utmost importance to have specially selected men taught by an expert in welding to handle the electric arc.

MISCELLANEOUS

The question of how the central station should bill the current user is old and it has occupied the time and thought of the best electrical brains for many years to devise equitable means of charging for power.

It is now quite generally recognized that rates should be figured to cover two parts which go to make up central station costs—fixed charges and operating expenses. The fixed charges depend on the amount of capital invested and continue whether much or little current is furnished. Operating expenses, however, vary with the actual amount of current consumed.

In selling power, therefore, to customers central stations establish a rate to cover their fixed charges and usually designated as a demand charge. Operating expenses are met by establishing an energy charge at a certain rate per K.W.H.

The maximum demand of a consumer's installation is the largest amount of power required at any one time (usually over a 15 minute interval) during the period covered by the bill (generally one month), and of course varies greatly from day to day. An unusually heavy load may occur during the first few days of the month whereas during the remainder of the month only a normal load is required. The demand charge for the month, therefore, is fixed by the maximum occurring during any one single period.

Because of this condition and the fact that the demand charge usually comprises from one-third to one-half of the total power bill, means of controlling the maximum demand yield very great reductions in demand and consequently a great saving in the cost of power.

The "Edmoore" Power Demand Limitator was developed to limit maximum demands or peak loads by automatically reducing or interrupting one or more

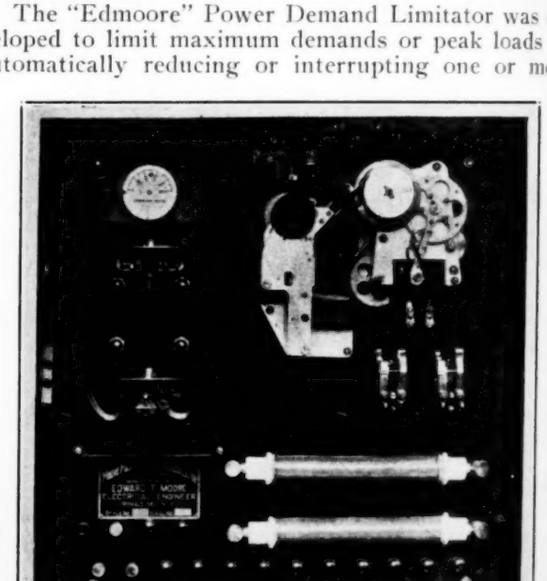


FIG. 8.

power consuming units comprising part of the load. In the case of electric melting furnaces the Limitator functions to raise the electrodes in the furnace a slight amount to effect the desired load reduction. When electric annealing furnaces are involved, one or more sections of the heating element are disconnected in order to reduce the load. In motor applications it is generally necessary to stop the motor where the driven machine is such that this can be done. Howe necessary to shut down the motor as a solenoid operated valve placed in the air intake of the compressor will reduce the mechanical load and therefore, the electrical input to the motor about fifty per cent. Nu-

merous other applications have been made among which is an installation in connection with motor driven pulp wood grinders. When the peak load reaches the predetermined amount the Limitator causes the hydraulic pressure in the cylinders of the grinders to be reduced and therefore, the load on the driving motor.

Most installations generally have totalizing current and potential transformers installed in the main incoming power lines. An integrated watthour meter, into which is installed a special set of contacts, is then connected to the instrument transformers and as power is used intermittent impulses are given by the contact device. The greater the consumption of power, the greater the number of impulses which are transmitted from the contact device to a master control cabinet (Fig. 8) 18 in. x 18 in. x 7 in. In this cabinet mounted upon a panel is an electromagnetic gearing which receives the impulses from the watthour meter. Upon a shaft which is rotated by the gearing is mounted the load adjustment cam which, when the load has reached the predetermined setting, causes a set of contacts to close and energize a control relay. This relay is connected to the power consuming unit as desired, and thereby causes a reduction or interruption of the load.

The Limitator may be constructed for any length of demand period and the timing mechanism may be clock driven or synchronous motor drive.

In motor installations such as described above the load is controlled on an integrated basis. However, in some cases, notably electric furnace applications, instantaneous control of momentary peaks is also desirable and is accomplished by using a watt element directly connected to the totalizing instrument transformers. In installations where a different demand rate is in effect days and nights it is possible to provide automatic operation for a given demand setting at one period and a different setting for another.

TOTAL LOAD ON A LARGE STEEL WORKS

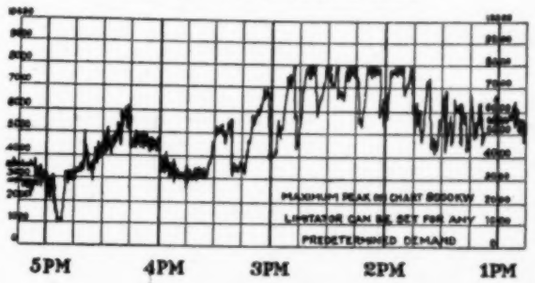


FIG. 9.

It must be understood that the Limitator is set so that the necessary load demand for the best and most economical operation is not interfered with to any extent, but the short interval peaks are eliminated. It is these peak demands (Fig. 9) which greatly increase the demand charge and as no benefit is derived from short time peaks, their positive automatic control has been a means of saving many dollars, in addition to improving the load factor. Central stations in general therefore, are approving as their systems also share in the benefits of load factor improvement.

Additions to Rolling Mills at Steubenville Plant of the Wheeling Steel Corporation

By M. J. CONWAY*

IN order to balance the semi-finished and finished departments of the Corporating by supplying sheet bar to the Wheeling mills from Steubenville, a demand was created for greater tonnage from the Steubenville plant which had to be obtained through the installation of new mill equipment.

Ideal conditions cannot be hoped for when installing new equipment in an old steel plant, and Steubenville did not prove an exception to the rule, as the layout was naturally affected by limited site conditions.

The additional mill equipment consisted of a 35" two-high blooming mill and a 19" continuous bar mill, with the necessary shears, delivery and loading equipment.

Auxiliary to the additional mill equipment mentioned, a new boiler plant, power plant, gas producer plant and two additional rows of soaking pits were installed.

*Combustion Engineer, Wheeling Steel Corp., Steubenville, Ohio.

Boiler Plant.

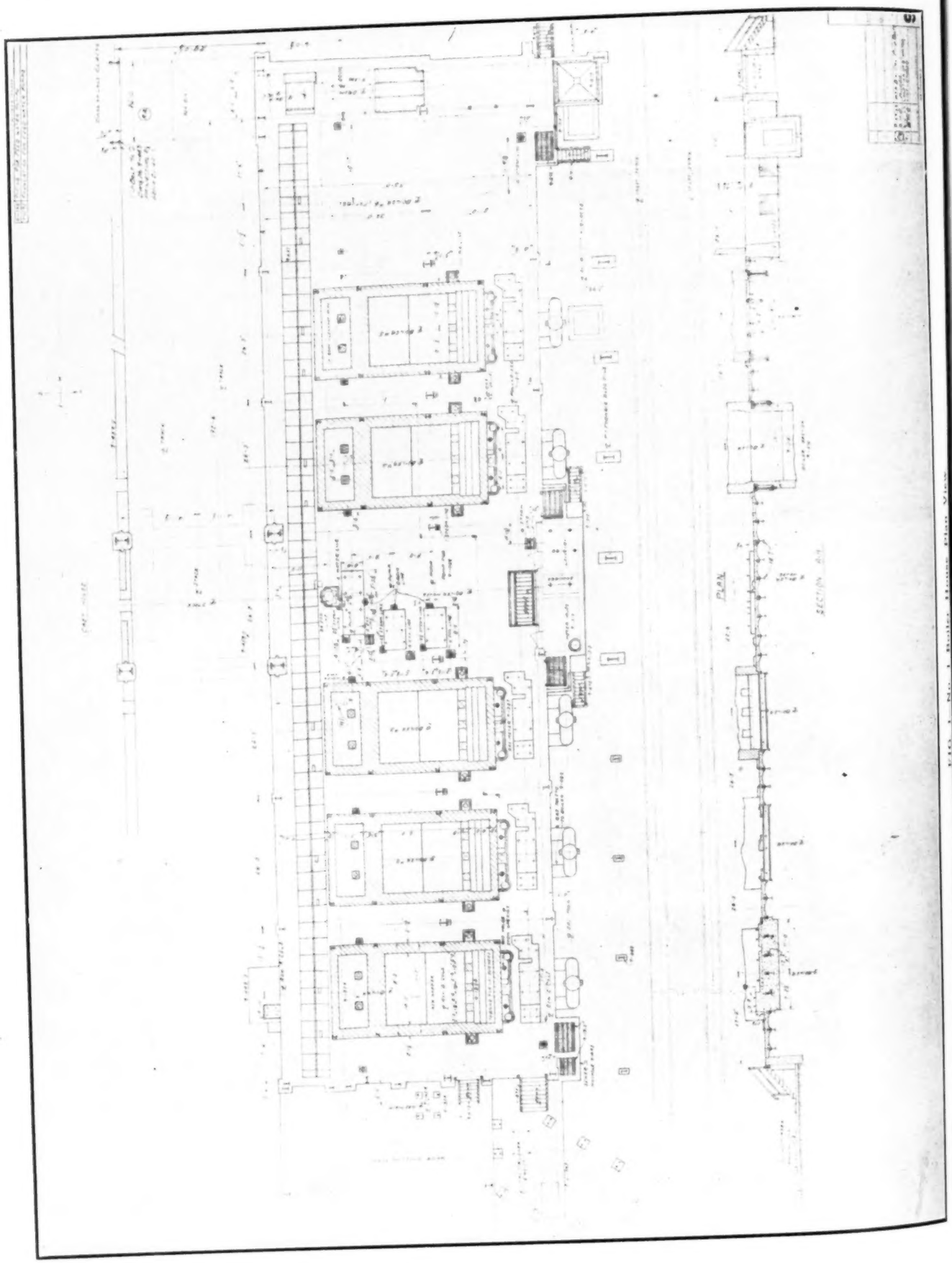
In order to provide the steam-driven units of the new mill with steam at 240 lbs. pressure and 125° F. superheat, a new boiler plant was installed consisting of five 829 H.P. Connelly boilers, equipped with Elesco super heaters.

A general arrangement of this boiler plant is shown in Fig. 1, and a sectional view of one of the boilers is shown in Fig. 2.

The boiler setting was built for the burning of powdered coal supplied by motor driven Aero unit pulverizers, except during the week-end, when surplus coke oven gas is used to prevent its being wasted.

Tracy steam purifiers were installed in the steam drums of the boilers to insure delivery of clean steam for distribution to the engines.

In order to prevent excessive boiler popping directly after the mills have finished rolling, or during a temporary mill delay, a passover valve allows the excess steam generated to bleed into the 150 lbs. pressure steam system which supplies steam to the older units in the plant.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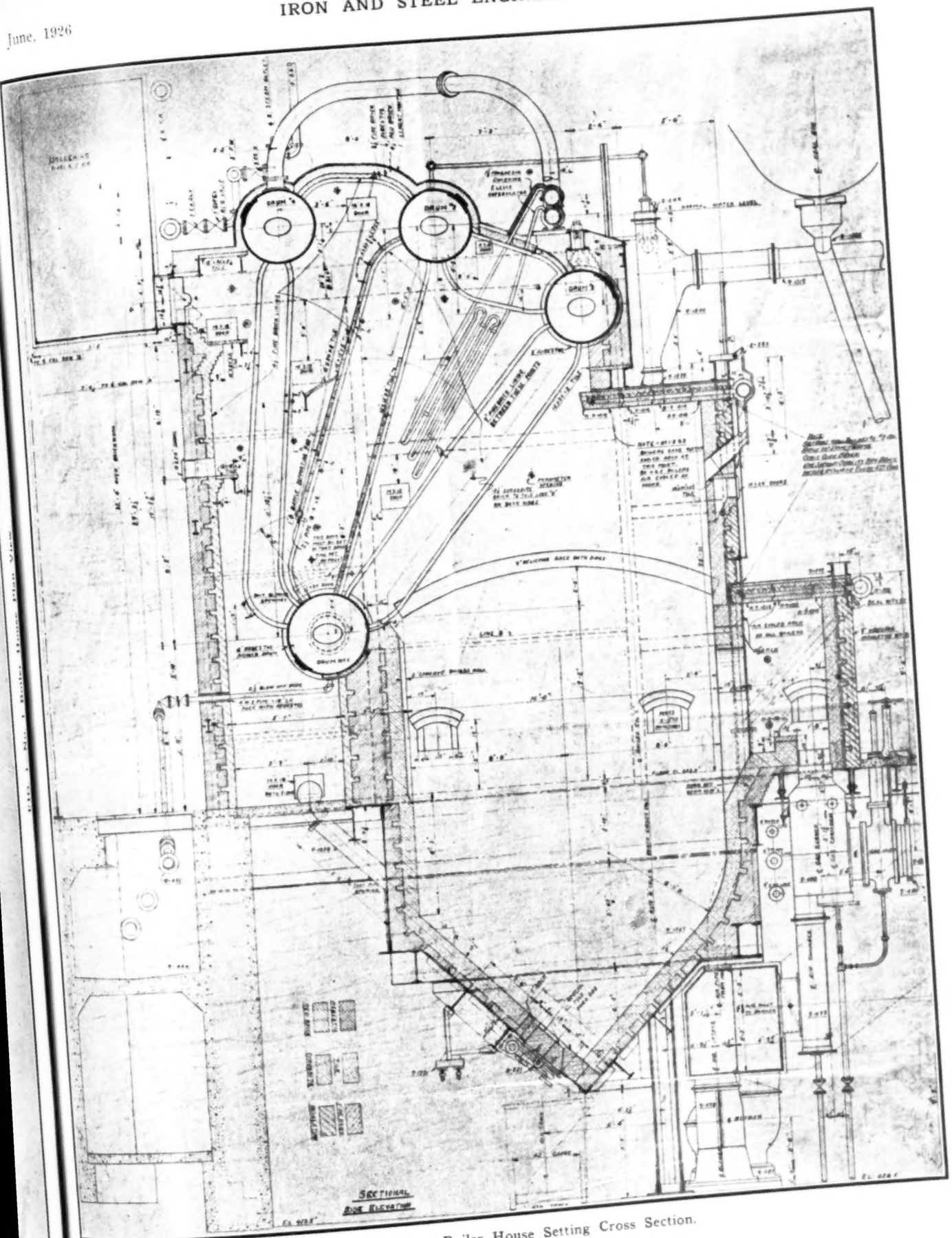


FIG. 2.—No. 1 Boiler House Setting Cross Section.

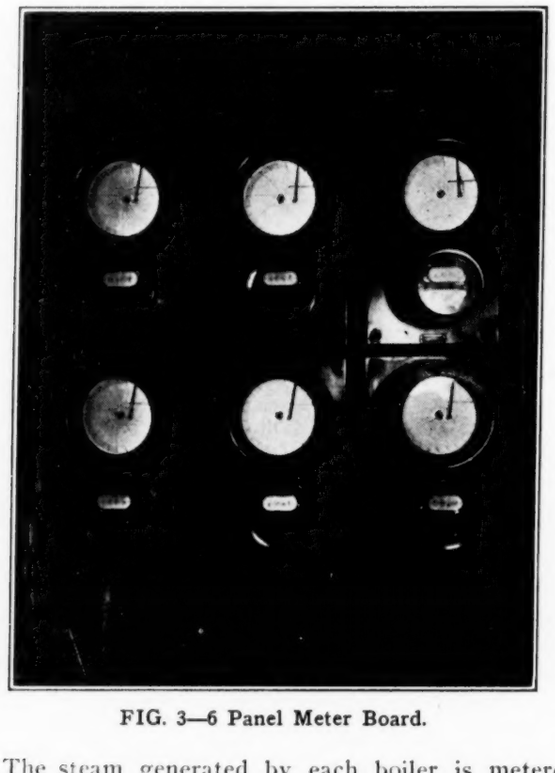


FIG. 3—6 Panel Meter Board.

The steam generated by each boiler is metered by Bailey boiler meters, and the steam distributed to the various mill engines and boiler house auxilliaries together with the steam bled to the low pressure system is measured by Republic flow meters, a six-panel installation of the latter type of meter is shown in Fig. 3. This panel is placed in the instrument room of the boiler plant where it can be easily seen by the boiler house foreman and operators.

Gas Producers and Soaking Pits.

The gas producer plant consists of six R. D. Woods heavy duty gas producers, each having a rated capacity of 5,000 lbs. of coal per hour. These producers are fully mechanical from the coal feed to the ash discharge and are equipped with turbo blowers to substitute the multi-stage jet blowers at the higher capacities.

FIG. 5—Ingot Entering Mill.

The two additional rows of soaking pits are duplicates of the rows of pits that were already in use. The cover removing mechanism is operated

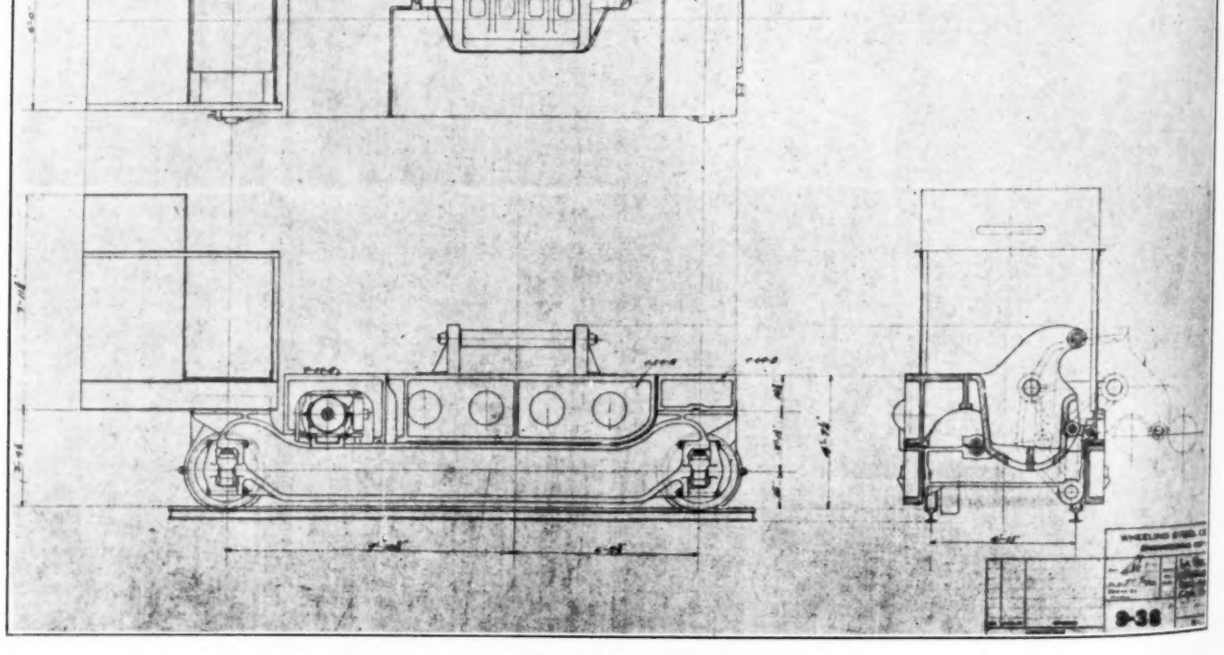


FIG. 4—Ingot Buggy.

by electric motors as are the six-way McKee gas valves which reverse the flow of gases on these pits.

Additional equipment included a pit crane and an ingot buggy. See Figures 4 and 5.

Bloom Mill.

The 35"-2-high reversing blooming mill, together with the pinions and manipulators, were designed and built by the Mackintosh-Hemphill Company.

The mill is designed for 32" diameter rolls, having a body length of 84" and a maximum lift of 31". The roll housings are of cast steel with closed top and rest on heavy cast steel shoes having a spread of 8'-4", which afford a substantial base for the entire mill structure.

The top roll is balanced by two hydraulic cylinders supported on the outside of each roll housing. The plungers support a steel casting lifting beam, from which rods are suspended which pass through the housings and connect to the top roll carriers.

This type of roll balance having the lifting beam on top of the mill gives to the operator an unobstructed view through the mill which is advantageous and important.

The screwdown is operated by a 150 H.P. General Electric Engine type motor having a full load speed of 100 R.P.M. and imparting to the screws a speed of about 15'-0" per minute. The slow speed motor eliminates the use of gear reductions making the screwdown exceptionally compact.

The roll train is entirely equipped with Universal Couplings to completely eliminate any backlash between the rolls, spindles, pinions and engines. Both top and bottom spindles are carried in bearings and are therefore well supported. See Figs. 6 & 7.

The pinions are designed with a wide face having double helical teeth, the large diameter of the extra long necks providing ample bearing surface. The pinions run in oil and are therefore completely enclosed.

The manipulators are hydraulically operated and are of the overhead type, possessing ample speed and strength to handle the tonnage for which the mill was designed.

Continuous Mill.

The Morgan continuous bar mill which is driven by a Nordberg uniflow engine is comprised of eight trains of rolls, designed with extra distance between roll centers for throwing loops between the last five trains of rolls.

The mill also has three stands of vertical edging rolls, the housings being designed so that the rolls can be easily and quickly changed.

On the entry side of the mill a preliminary shear is installed for cropping and cutting the hot steel

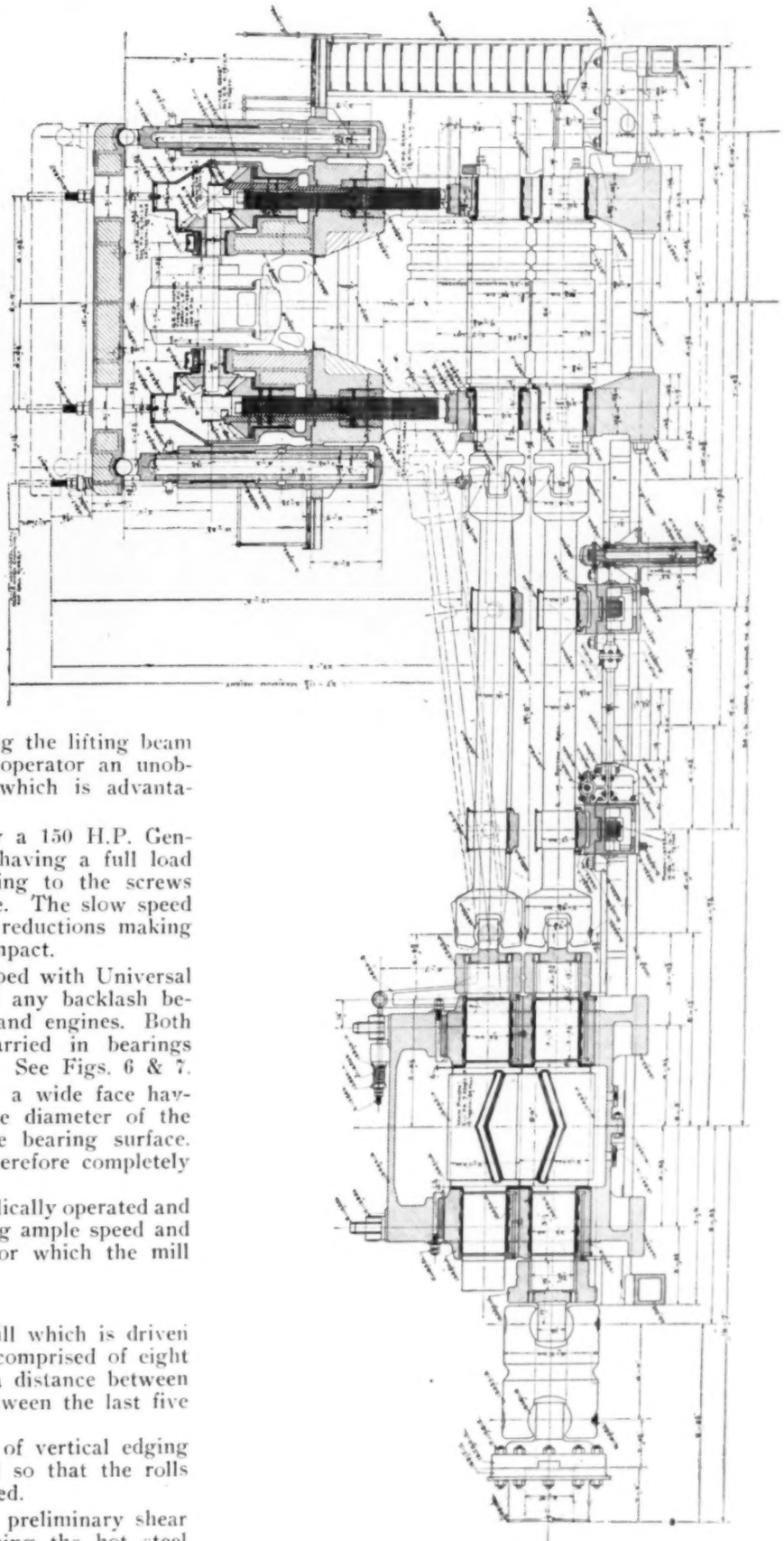


FIG. 6—View of Roll Train.

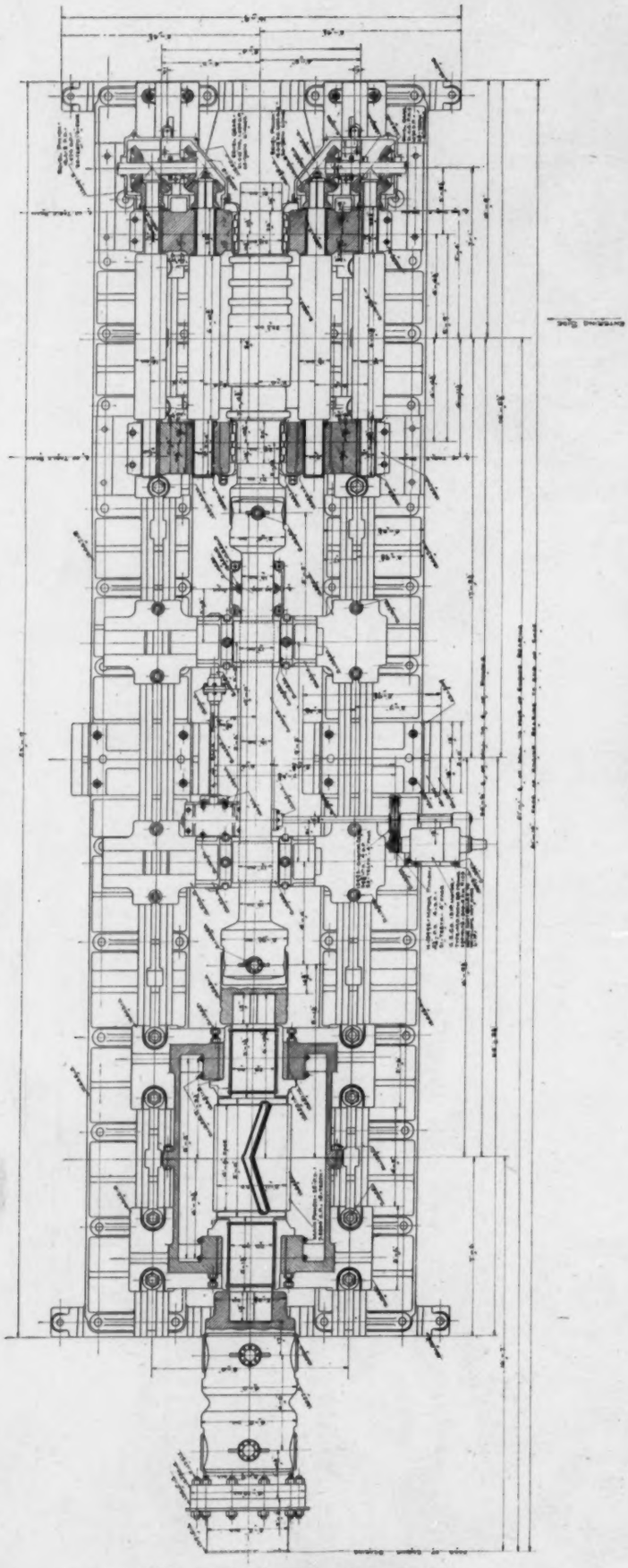


FIG. 7—Outline Drawing of Mill.

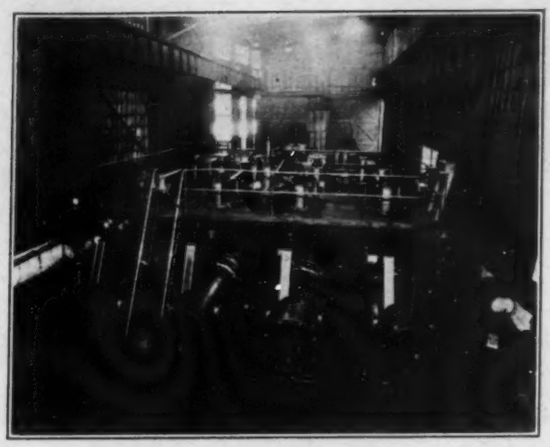


FIG. 8—35 In. Mill Engine.

FIG. 9—19 In. Mill Engine.

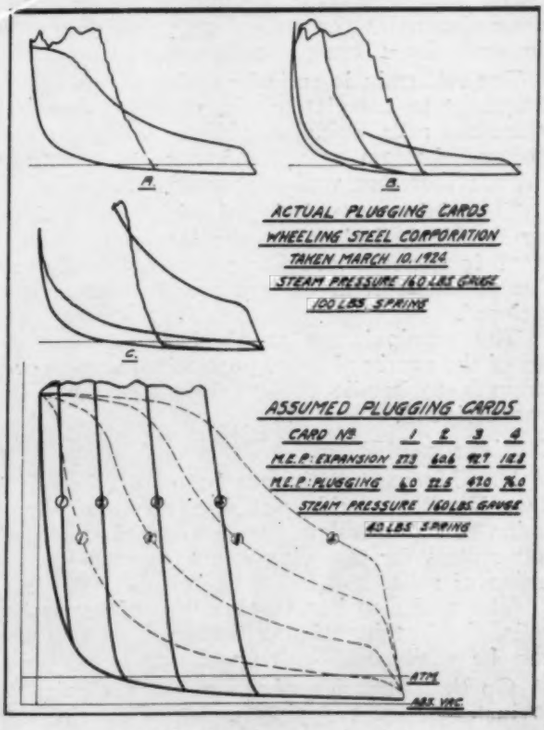


FIG. 10—Plugging Cards.

blooms as delivered from the blooming mill. This shear is operated by a 25 H.P. Reliance motor.

Installed on the delivery side is an Edwards-Carroll patented steam actuated flying shear for cutting the hot sheet bar and skelp as the material issues from the mill.

The sheet bar, after passing from the flying sheers and being cut to suitable length, passes through a set of pinch rolls to the necessary piling equipment.

Engines.

Probably the most interesting feature about the new mill is the Nordberg Uniflow Engines, more especially, the reversing uniflow engine driving the 35" Blooming Mill. Fig. 8.

The Wheeling Steel Corporation having already successfully applied uniflow engines to their sheet mill operations at Wheeling and Portsmouth, felt that similar good results could be obtained by the uniflow principle applied to a reversing blooming mill engine.

It has generally been conceded that the previous practice of driving blooming mills by means of the type of reversing engine in general use was very wasteful in the use of steam and that equally as large a saving could be procured by the use of the uniflow principle if applied to the reversing mill as had been obtained by the use of uniflow drives adapted to non-reversing mills.

One of the big outstanding features which caused the uniflow principle to be seriously considered for reversing mill practice was the progress being made by the electrification of this type of mill. Of course, practically all of the installations of electrically driven mills were modern, getting their power from modern sources and employing the very best engineering ability in their application.

Therefore, the only installations with which the electric driven mills could be compared were the old style reversing engines receiving steam from old steam plants, some of which have been in operation 20 years or longer.

It appealed to the Wheeling Steel Corporation, that if a modern steam plant with a correct system of steam piping, coupled with the uniflow principle of reversing blooming mill engine was employed, that very economical results could be obtained with a great reduction in the steam consumed per ton of steel rolled and at the same time with a great saving in first cost of the installation as compared with an electric driven mill.

With this thought in mind, the Nordberg Company received an order for the first reversing uniflow steam engine for a blooming mill to be built in the world and at the same time an order for an exact duplicate of the reversing engine in the form of a continuous mill engine. Fig. 9.

The engines driving both mills are identical, having the same valve gear and details throughout, with the exception that the blooming mill engine is a reversing engine and the continuous mill engine is not.

The blooming mill was designed to roll the ingots into blooms of a suitable size to be fed to the continuous mill to be rolled into sheet bar and also to roll slabs of various sizes for use at the jobbing and plate mills.

The steam is supplied to the engines from the new boiler plant and great care was taken to confine the steam piping to as large and as few mains as practicable, so as to concentrate the transmission of the steam and prevent the usual radiation losses, which are prevalent in the average steel mill steam piping system.

By the use of a few pipes of the proper size to transmit the superheated steam at a high velocity to receivers placed at the engines, the usual drop in pressure was greatly reduced and the rapid travel of the steam through the pipes reduces the usual losses of condensation per pound of steam transmitted.

The Company decided to operate their engines with steam at 240 lbs. gauge pressure, 125° F. superheat and a vacuum of 26 inches. The problem for the engine builder therefore was to build a fast reversing blooming mill engine and a continuous mill engine of simple and rugged design to stand up under the severe strain of hard rolling mill service and operate economically.

The engine manufacturer approached this problem from a very wide angle, investigating thoroughly the possibilities of a compound engine, a single expansion full poppet valve three-cylinder engine and a poppet valve uniflow engine.

Fig. 10 illustrates plugging cards as anticipated by the engine builder and actual plugging cards taken on the engine while in normal operation.

The assumed cards show the M.E.P. available to stop the engine at different positions of the valve gear, and the dotted lines, expansion cards for the same gear positions.

The actual plugging card A is followed by an expansion card; on B the indicator caught part of an expansion stroke, a light positive and two negative cards, on card C the engine stopped on the back stroke and reversed, the plugging steam expanding and accelerating the engine.

Figs. 11, 12 and 13 show the inertia forces and moments of a two crank compound, a three and four cylinder uniflow engine respectively and also the fluctuation of torque during one revolution.

The reciprocating and rotating parts leave an unbalanced horizontal force on the compound engine, but disappear entirely on the three and four cylinder engines. The vertical forces of the rotating parts are perfectly balanced on the three cylinder engine and show a greater unbalanced force on the compound than on the four cylinder uniflow engine.

The combined horizontal as well as the vertical moments of these forces are very much smaller on the four cylinder engine than on either the compound or three cylinder engine.

As a basis for the conventional twin tandem compound engine, use was made of the test on the large and well developed 2-46-76-60" reversing engine and rolling mill at the Youngstown Sheet & Tube Co., Youngstown, Ohio, by Karl Nibecker, as published in the Proceedings of the Engineers Society of Western Pennsylvania, July, 1914.

Fig. 14 shows an average combined indicator card of the Nordberg uniflow reversing engine doing the same amount of rolling work under identical steam conditions as the compound engine and also

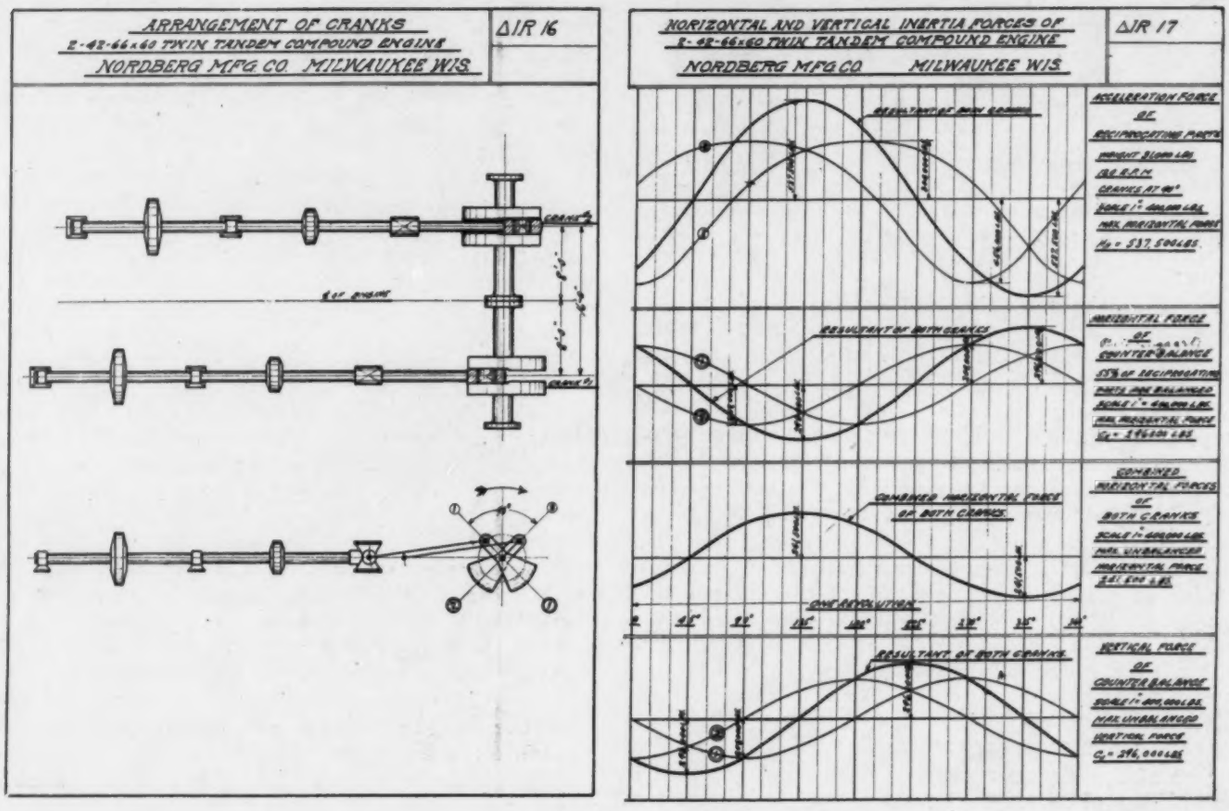


FIG. 11-A.

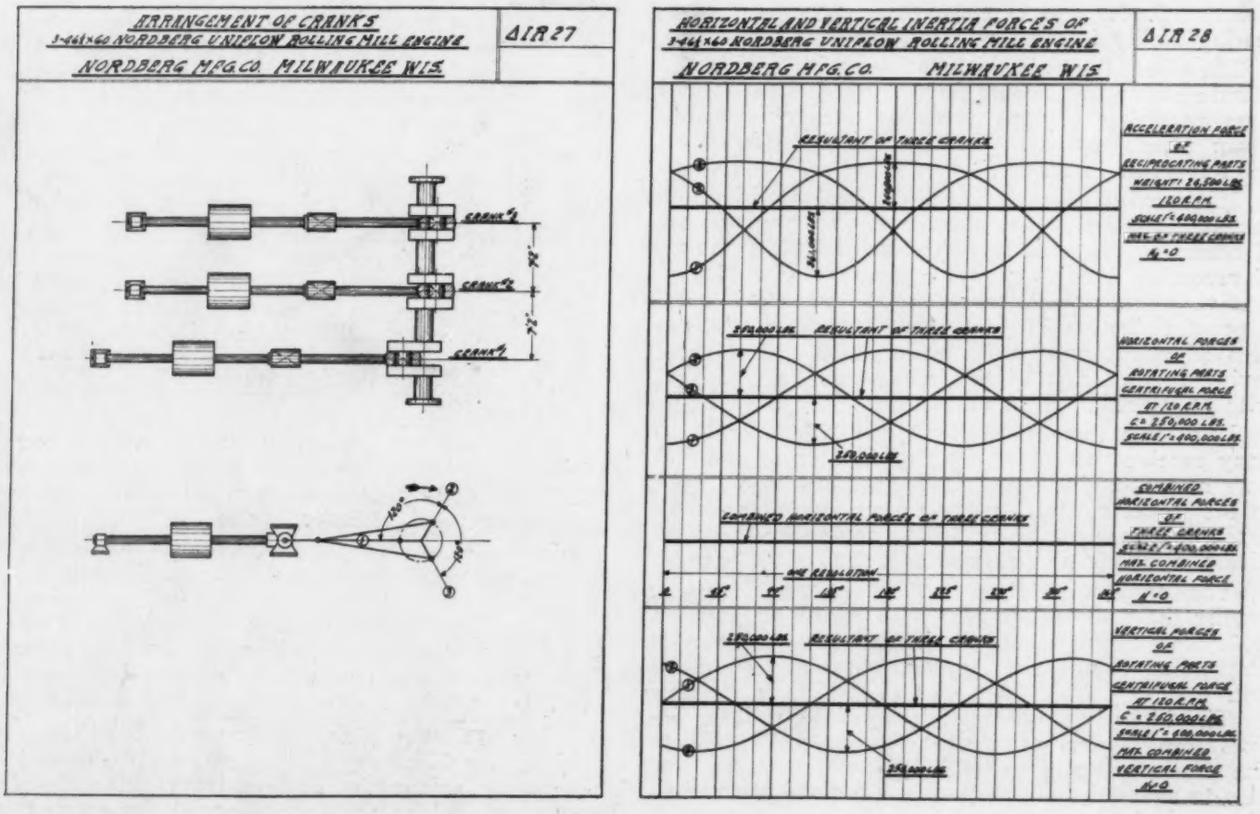
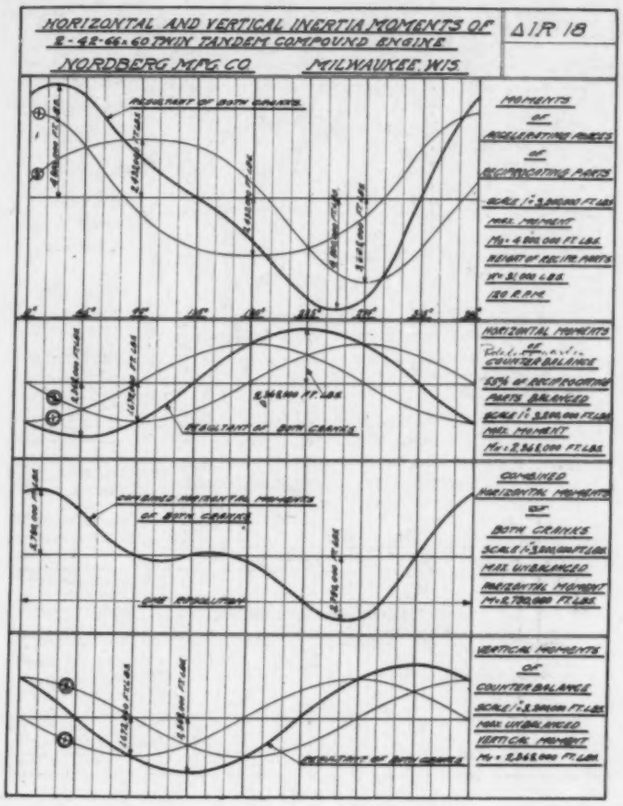


FIG. 12-A.


HORIZONTAL AND VERTICAL INERTIA MOMENTS OF
Δ1R 18
E-42-66-60 TWIN TANDEM COMPOUND ENGINE
NORDBERG MFG CO MILWAUKEE WIS
RESULTANT OF BOTH CRANKS
MOMENTS OF ACCELERATING FORCES OF RECIPROCATING PARTS
HORIZONTAL MOMENTS OF COUNTERBALANCE
50% OF RECIPROCATING PARTS BALANCED
COMBINED HORIZONTAL MOMENTS OF BOTH CRANKS
ONE REVOLUTION
VERTICAL MOMENTS OF COUNTERBALANCE

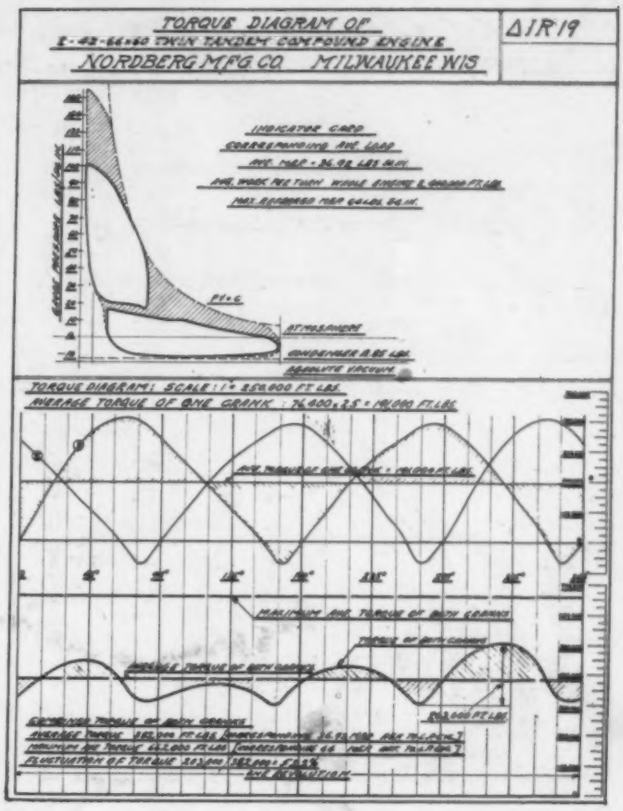
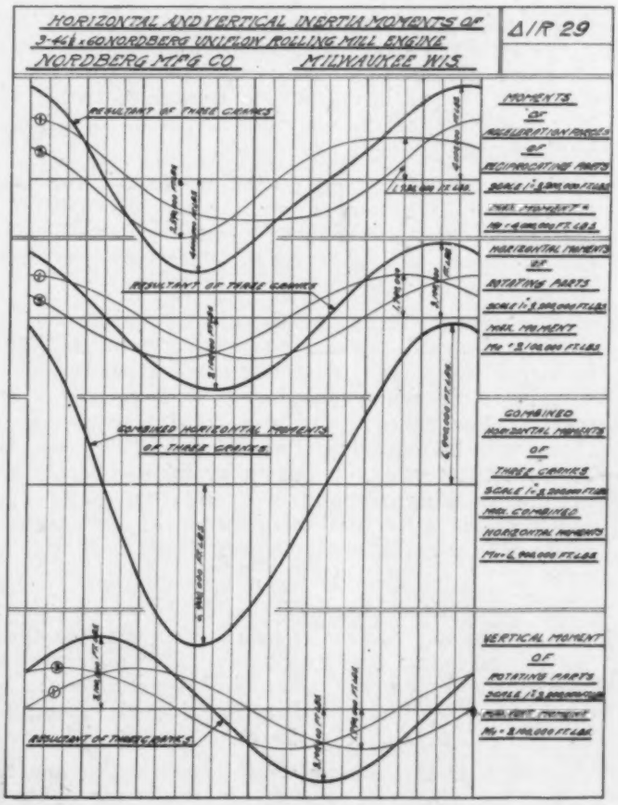


FIG. 11-B.


HORIZONTAL AND VERTICAL INERTIA MOMENTS OF
Δ1R 29
3-46½-60 NORDBERG UNIFLOW ROLLING MILL ENGINE
NORDBERG MFG CO MILWAUKEE WIS
RESULTANT OF THREE CRANKS
MOMENTS OF ACCELERATION FORCES OF RECIPROCATING PARTS
HORIZONTAL MOMENTS OF ROTATING PARTS
COMBINED HORIZONTAL MOMENTS OF THREE CRANKS
VERTICAL MOMENT OF ROTATING PARTS

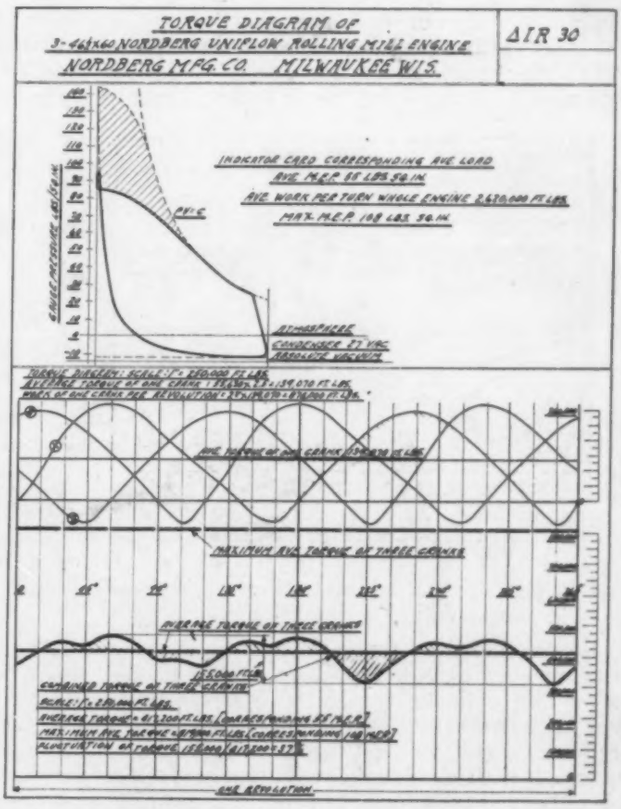

TORQUE DIAGRAM OF
Δ1R 30
3-46½x60 NORDBERG UNIFLOW ROLLING MILL ENGINE
NORDBERG MFG CO MILWAUKEE WIS
INDICATOR CARD CORRESPONDING AVE LOAD
AVE M.E.P. 88 LBS. SQ. IN.
AVE WORK PER TURN WHOLE ENGINE 2,670,000 FT. LBS.
MAX. M.E.P. 108 LBS. SQ. IN.
PV=C
ATMOSPHERE
CONDENSER 27 INS. ABSOLUTE VACUUM
MAXIMUM AVE. TORQUE OF THREE CRANKS
AVERAGE TORQUE OF THREE CRANKS

FIG. 12-B.

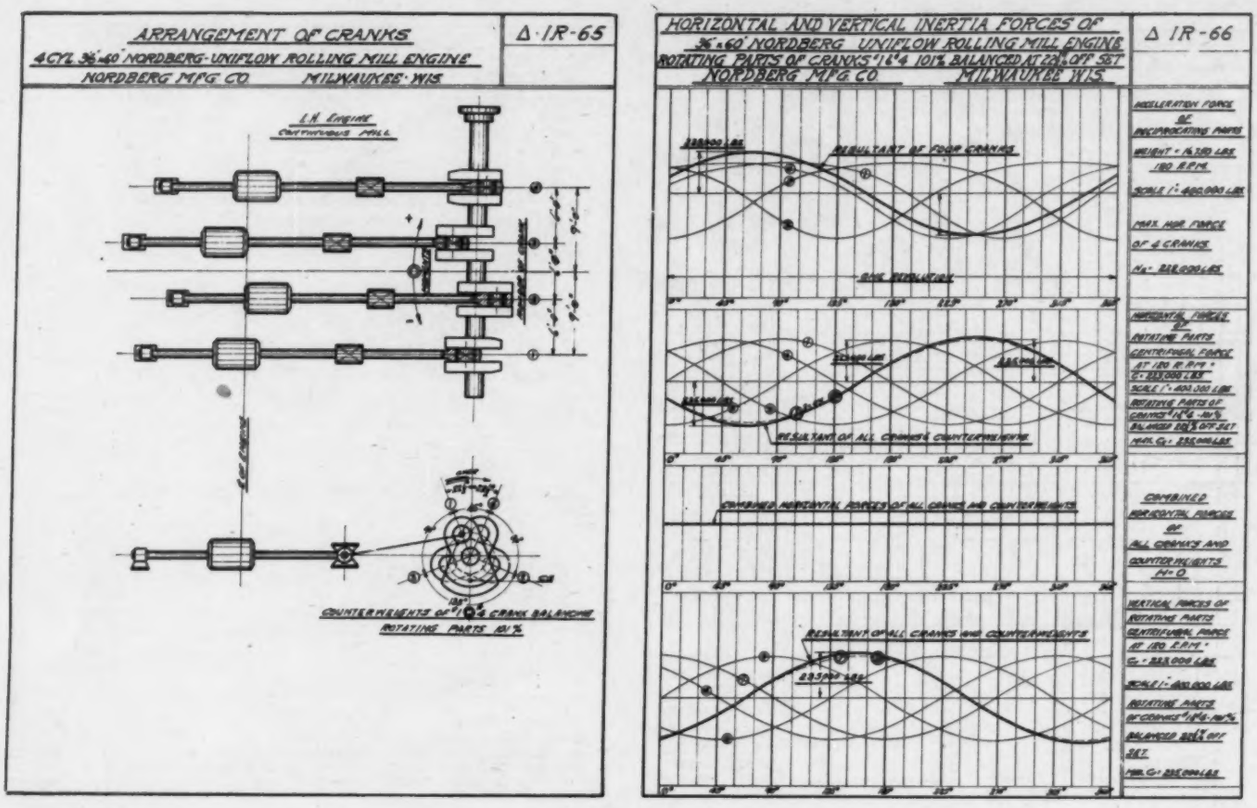

ARRANGEMENT OF CRANKS
Δ·IR-65
4 CYL. 34"-40" NORDBERG-UNIFLOW ROLLING MILL ENGINE
NORDBERG MFG CO. MILWAUKEE·WIS
HORIZONTAL AND VERTICAL INERTIA FORCES OF
Δ IR-66
34" x 60" NORDBERG UNIFLOW ROLLING MILL ENGINE
ROTATING PARTS OF CRANKS 1-2-4 101% BALANCED AT 22½° OFF SET
NORDBERG MFG. CO. MILWAUKEE WIS.
RESULTANT OF FOUR CRANKS
RESULTANT OF ALL CRANKS AND COUNTERWEIGHTS
COMBINED HORIZONTAL FORCES OF ALL CRANKS AND COUNTERWEIGHTS
RESULTANT OF ALL CRANKS AND COUNTERWEIGHTS

FIG. 13-A.

when supplied with steam at 240 lbs. gauge pressure and 125° F. superheat.

During the working strokes in the compound engine an average of 66.6 per cent of the available M.E.P. is realized, while in the uniflow this amounts to 77.7 per cent under the same operating conditions and 79.4 per cent for 240 lbs. steam pressure

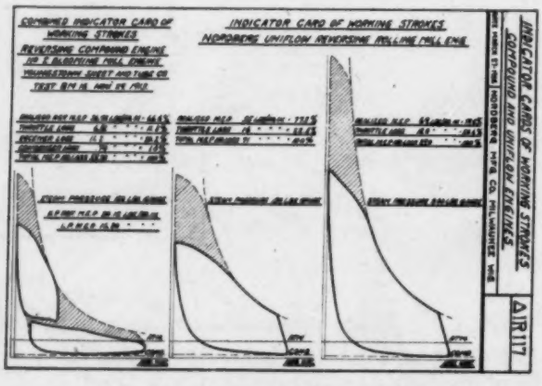

COMBINED INDICATOR CARD OF WORKING STROKES
INDICATOR CARD OF WORKING STROKES
NORDBERG UNIFLOW REVERSING ROLLING MILL ENG.
INDICATOR CARDS OF WORKING STROKES
COMPOUND AND UNIFLOW ENGINES
ΔIR17

FIG. 14—Combined Indicator Card

was during the actual operation of the mill found to be a conservative assumption.

By eliminating the receiver loss and utilizing to a greater extent any degree of vacuum, its inherent low cylinder condensation and high economy over a wide range, practically the same from 25 per cent load to 150 per cent load and being equipped with double heat, balanced poppet valves, the only valves which can be made tight and remain so against high steam pressure and superheat, gave the uniflow engine a very distinct economical advantage over any other type of steam driven prime mover.

In order to determine the number of cylinders, the starting torque diagrams, Fig. 15 and Fig. 16, were prepared showing maximum average and minimum torque in relation to cut-off of two, three, four and five crank engines of equal total piston displacement.

At the coupling end of the crankshaft the average torque of either engine for a given cut-off is the same, the maximum torque increases while the minimum available torque decreases the fewer cranks are used.

The two-crank engine therefore requires a larger shaft and much heavier reciprocating parts than a four-crank engine; it does not start as smoothly nor run as even when the ingot is approaching the rolls at low speed. The rolls will bite better and there will be less slippage during rolling the more uniform the torque. From an average indicator card of the working strokes, a twin compound engine will produce a fluctuation of torque of 53.2 per cent, while a four-crank shaft engine shows only 27.5 per cent.

A short description of this four cylinder poppet valve reversing uniflow engine at this time may prove both interesting and instructive. The general arrangement is on the folllowing illustrations: Fig. 17 longitudinal section, Fig. 18 side elevation, Fig. 19 plan view, and Fig. 20 cross section.

The four throw crankshaft is carried in one bedplate, to which by means of crosshead slides the four clylinders are attached.

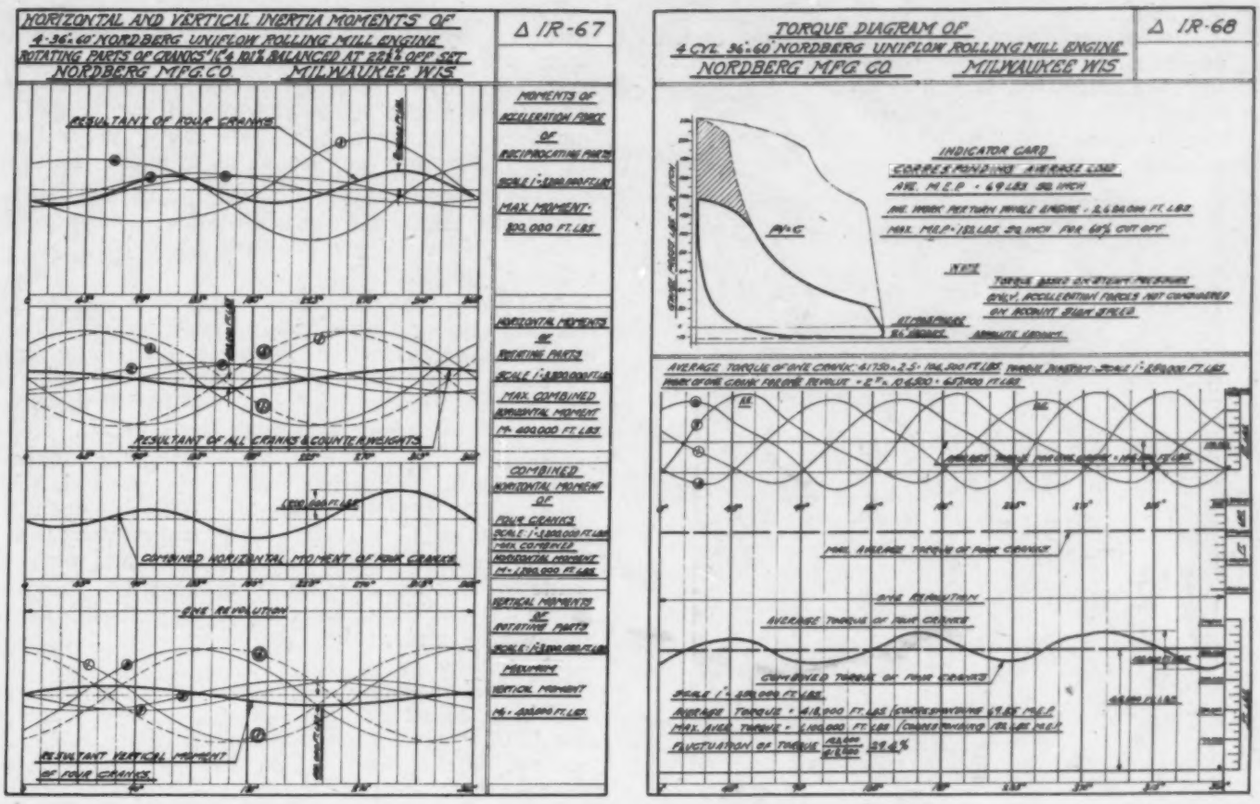

HORIZONTAL AND VERTICAL INERTIA MOMENTS OF
A-36"×60" NORDBERG UNIFLOW ROLLING MILL ENGINE
ROTATING PARTS OF CRANKS 1" & 101" BALANCED AT 22½° OFF SET
NORDBERG MFG. CO. MILWAUKEE WIS.
Δ IR-67
RESULTANT OF FOUR CRANKS
RESULTANT OF ALL CRANKS & COUNTERWEIGHTS
COMBINED HORIZONTAL MOMENT OF FOUR CRANKS
ONE REVOLUTION
RESULTANT VERTICAL MOMENT OF FOUR CRANKS
TORQUE DIAGRAM OF
4 CYL 36"×60" NORDBERG UNIFLOW ROLLING MILL ENGINE
NORDBERG MFG. CO. MILWAUKEE WIS.
Δ IR-68
INDICATOR CARD
AVERAGE TORQUE OF ONE CRANK
CUMULATIVE TORQUE OF FOUR CRANKS
AVERAGE TORQUE OF FOUR CRANKS

FIG. 13-B.

The bedplate is cast in three pieces, solidly joined together with links sunk into the walls to avoid flanges and consequent bending stresses and heavy tie rods going through the entire width. Into this frame are accurately fitted the five main bearings, each consisting of two circular shells, securely held in position by a cap bolted firmly down against the top shell and shims. The lower shell, fitting into the circular recess of the frame, may be rolled out without moving the shaft, by merely relieving the pressure of the shaft.

The crankshaft is built up of forged steel webs and straight pins, pressed together by a special process which ensures an absolutely correct shaft. The cranks are set as to give a power impulse every 45 degrees, to produce a maximum torque at whatever position the engine may stop and to give the most perfect running balance of the engine as a

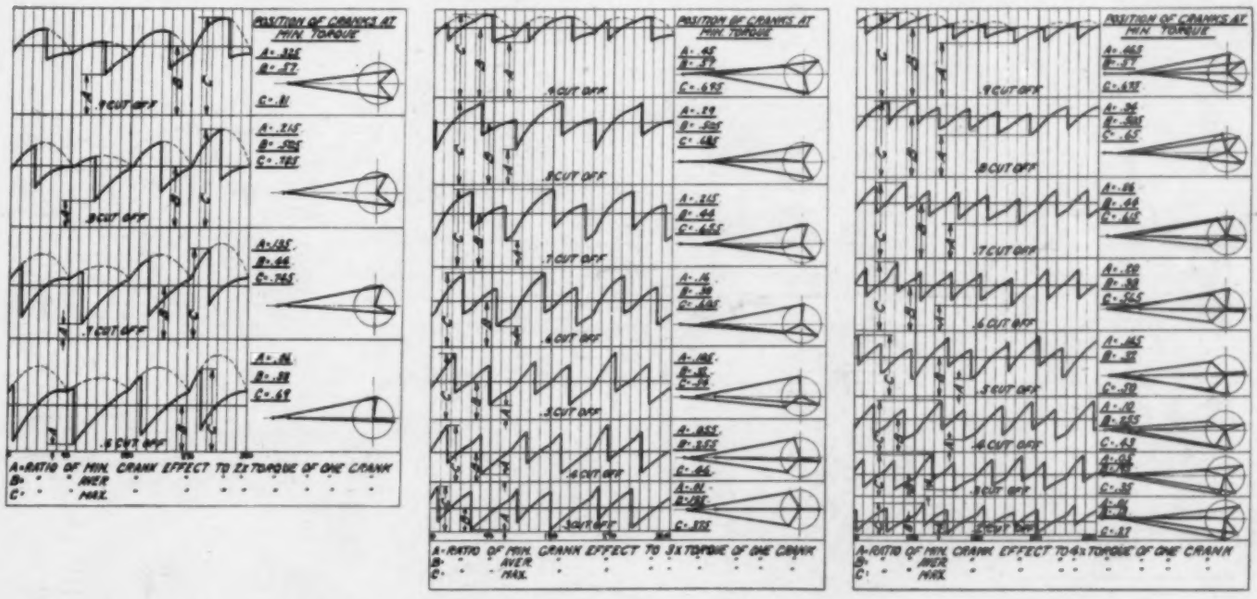

POSITION OF CRANKS AT MIN TORQUE
A-RATIO OF MIN. CRANK EFFECT TO 2X TORQUE OF ONE CRANK
A-RATIO OF MIN. CRANK EFFECT TO 3X TORQUE OF ONE CRANK
A-RATIO OF MIN. CRANK EFFECT TO 4X TORQUE OF ONE CRANK

FIG. 15—Starting Torque.

complete unit, the two outer cranks being proportioned for power balancing of the rotative forces and moments. Fig. 21.

The connecting rod is a hollow steel forging of the forked marine type. The wrist pins are part of the forged crosshead body to which the shoes, adjustable for wear, are firmly bolted. The hollow

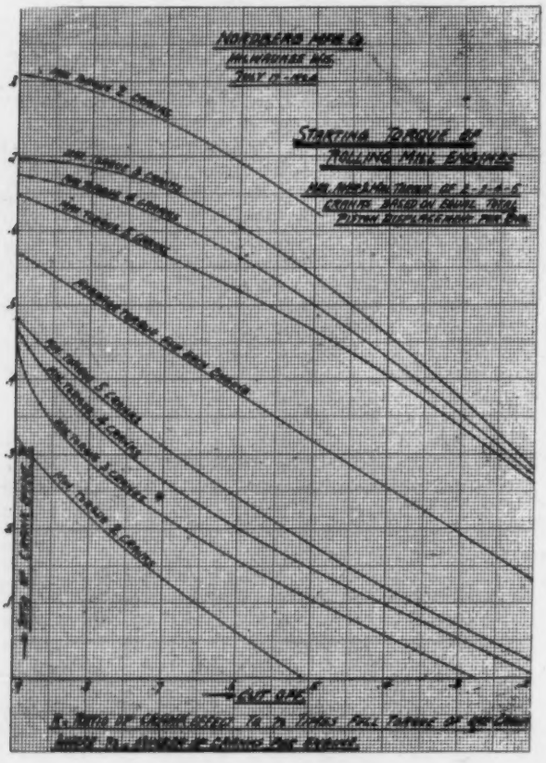


FIG 16—Starting Torque

piston rod is keyed to the crossheads, extends through the back cylinder head and is supported by a turned tail guide shoe.

The piston is made of cast steel, of strong but light construction, fitted with snap rings and steam tight keepers and is of the full floating type.

The cylinder proper consists of one principle casting carrying the valve chambers and the exhaust belt. Midway of the length of the cylinder there is a row of exhaust ports, which are uncovered by the piston at the end of each stroke and are joined together by a belt surrounding the cylinder and leading into the common exhaust manifold.

The steam chest contains the steam valves, their removable cages and bonnets, relief and auxiliary exhaust valves are made separate and bolted to the cylinder proper.

To the end of the crankshaft, opposite the mill side, is connected a five throw crank which through parallel rods drives an identical five throw crank on the layshaft, which runs across the engine on top of the crosshead guides and drives the steam eccentrics, forged integral with the layshaft.

From these eccentrics, there being one for each cylinder end, oscillating cams are operated, which without springs or dashpots positively open and close the double beat balanced poppet valves, seating in separate cages. These valves and seats are made of a special mixture of cast iron and are ground steam tight, insuring permanent tightness of the valves under high steam pressure and superheat.

The valve stem is flexibly connected to the valve and is made steam tight without the use of a stuffing box by carefully grinding and lapping. Grooves are cut on the stems, which become filled with condensate and oil thus forming a series of packing and preventing steam leakage.

Attached to the steam chest are over-compression valves Fig. 22. Should the steam pressure in the cylinder rise beyond that in the steam chest, these valves will automatically allow steam, trapped in the cylinder, to flow back into the steam pipe.

The engine is operated by means of a single lever control, Fig. 23, the manipulation of which reverses the engine, changes the cut-off and operates the throttle valve.

When this lever, located in the pulpit, is in the verticle position the reversing mechanism is in neutral with all the steam valves and throttle closed as shown in B, Fig. 24. Moving the lever forward

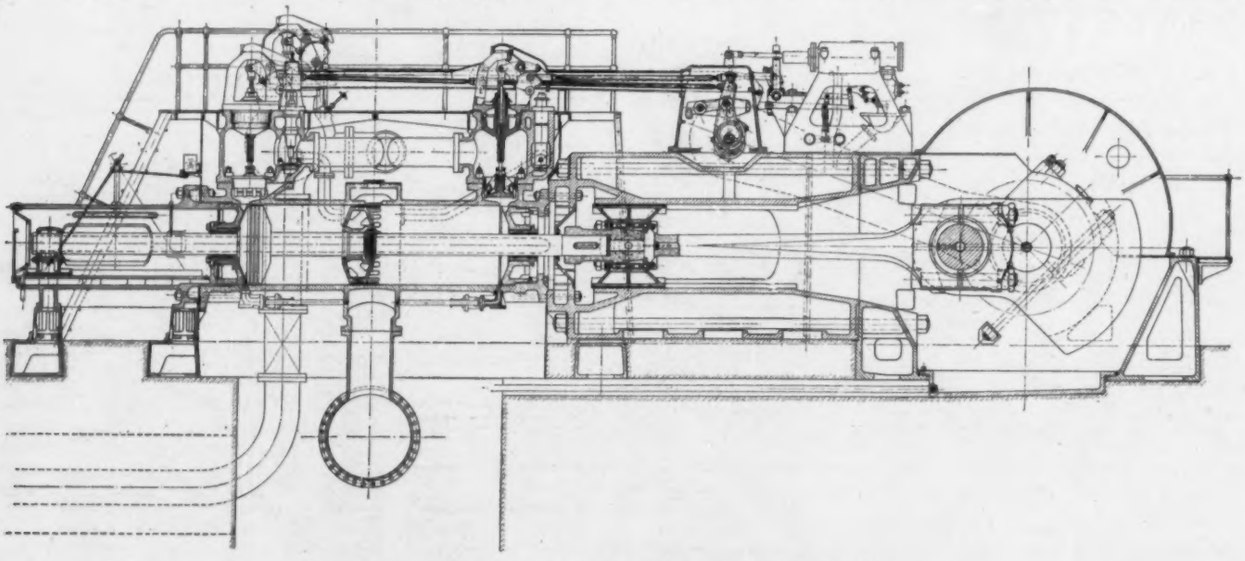


FIG. 17—35 In. Mill Engine Longitudal Section

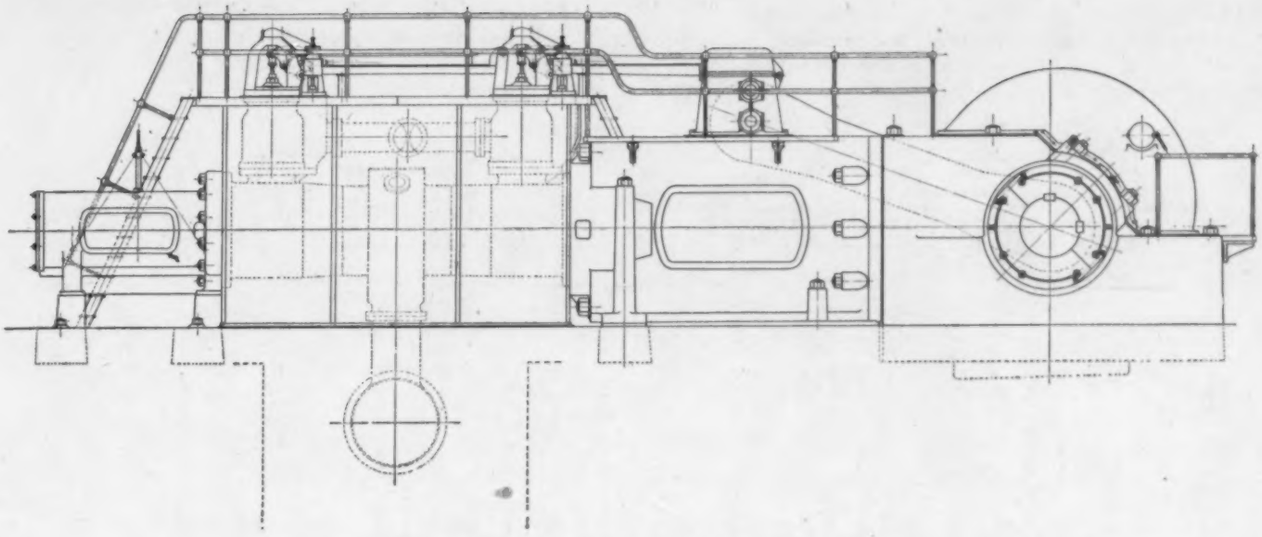


FIG. 18—35 In. Mill Engine Side Elevation.

or backward throws the valve gear in the running over or under position and opens the throttle valve the length of the cut-off being proportional to the throw of the lever. In the normal cut-off position the lever is pushed against a spring stop. This stop does not prevent the lever from being moved to the extreme positions, but will always bring it back to the normal cut-off again.

In case the engine should stall, small auxiliary exhaust valves, Fig. 25, are brought automatically into proper operation by the control lever being in its position for maximum cut-off in either direction, this is shown on Fig. 26 in cylinders, B, C, and D. Thus the engine may be made to exert more torque or reverse quickly under the most unfavorable condition by manipulation of the single lever beyond the points of normal cut-off.

By means of cross shafts and a system of floating levers the control lever actuates the operating valves, which control the oil to the reversing and

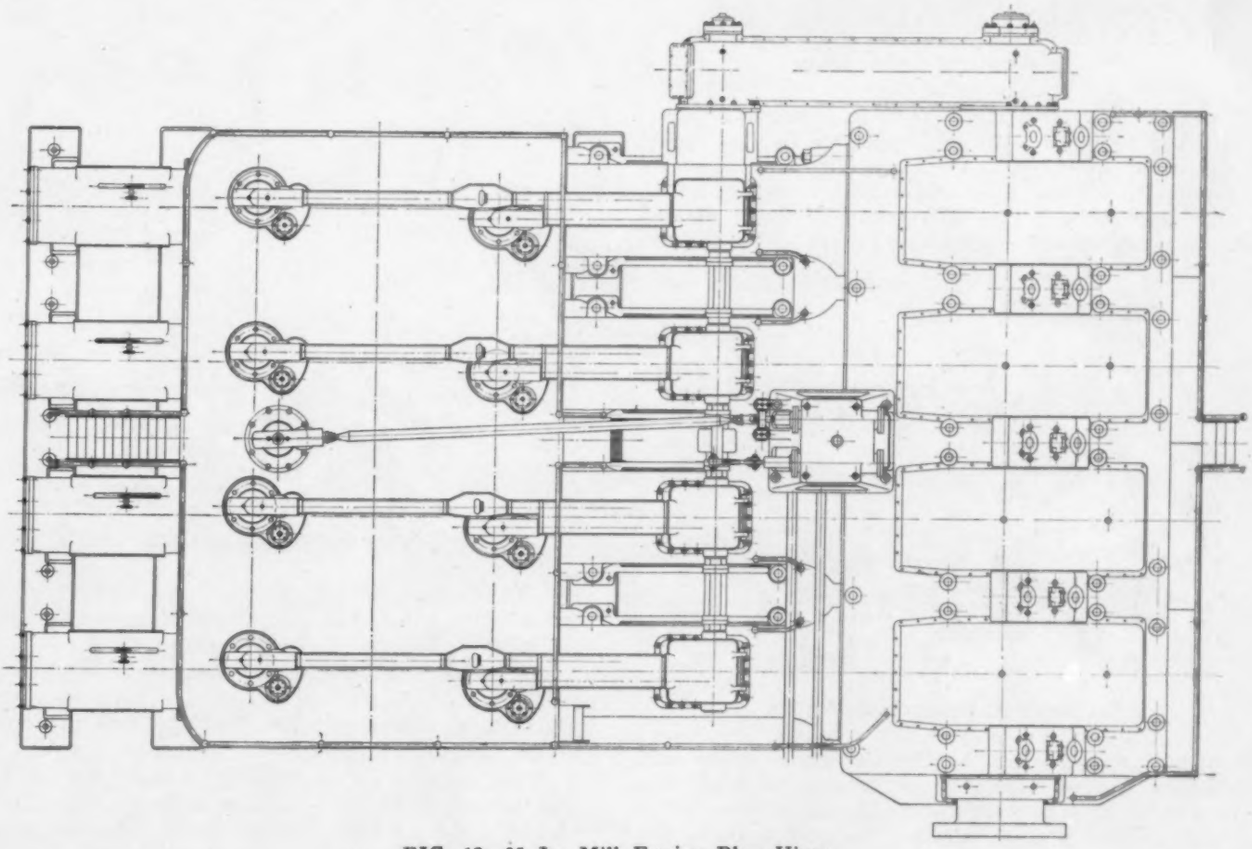


FIG. 19—35 In. Mill Engine Plan View.

throttle operating cylinders. These two double acting hydraulic thrust cylinders are located side by side on top of the bedplate and are operated by oil under pressure, furnished by motor driven pumps

The reversing valve gear is of the "Marshall Type," having one-link mechanism for each end of the cylinder. This Marshall gear is so designed so as to give correct steam distribution with sharp

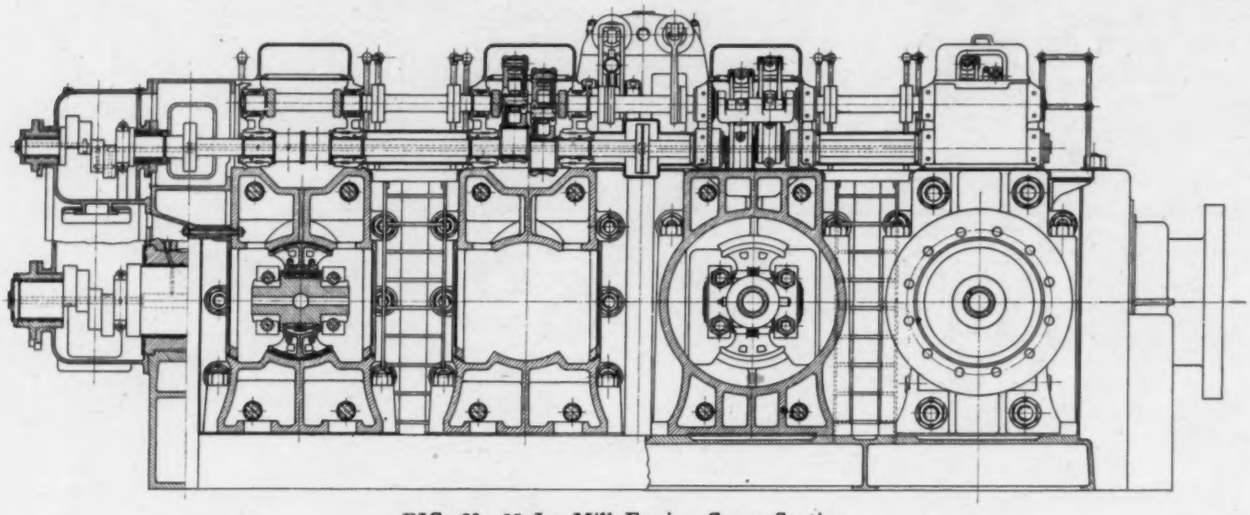


FIG. 20—35 In. Mill Engine Cross Section.

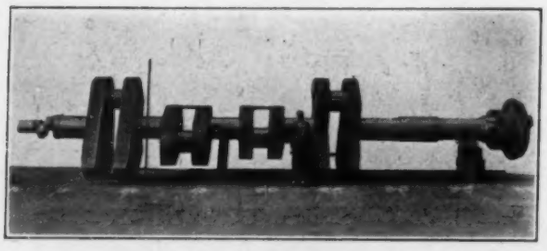


FIG. 21—Photo of Crank Shaft.

and stored in accumulators. Oil is admitted to and exhausted from the thrust cylinders by balanced poppet type hydraulic valves, so arranged that it is impossible for the inlet and outlet valves to open at the same time. The movement of these valves and therefore that of the thrust cylinders follow

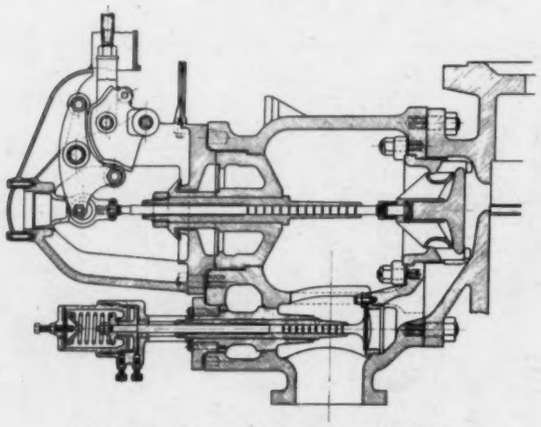


FIG. 22—Over Compression Valves.

absolutely the motion of the operating lever and whenever the operating lever comes to rest, the thrust cylinder also comes immediately to rest and is securely locked in that position, because both of the hydraulic valves are closed.

cut-off for each end of the cylinder throughout the entire range of cut-off in either direction.

The length of steam admission is controlled by the operators' lever and the engine is run entirely on the cut-off.

The engine is protected against overspeed by an overspeed governor and a safety stop. When the engine is running at 150 R.P.M. the overspeed governor rings a bell placed in the rollers pulpit and at

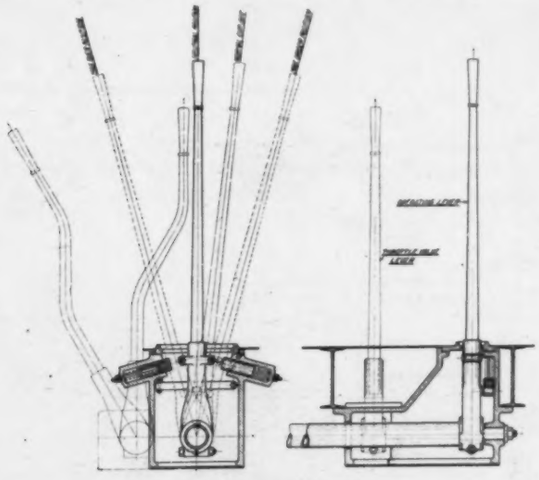


FIG. 23—Operating Lever.

160 R.P.M. the throttle valve is closed. By pulling the throttle lever back, the operator opens the throttle valve again and resets the governor.

At 160 R.P.M. the safety stop located under the throttle valve is closed and has to be reset by the engineer, this stop can also be tripped from stations in the engine room and at the rollers' pulpit.

The throttle valve, Fig. 27, located at the back end between the two middle cylinders is like the steam valve, of the double beat, balanced poppet valve type, mechanically opened and closed by a cam

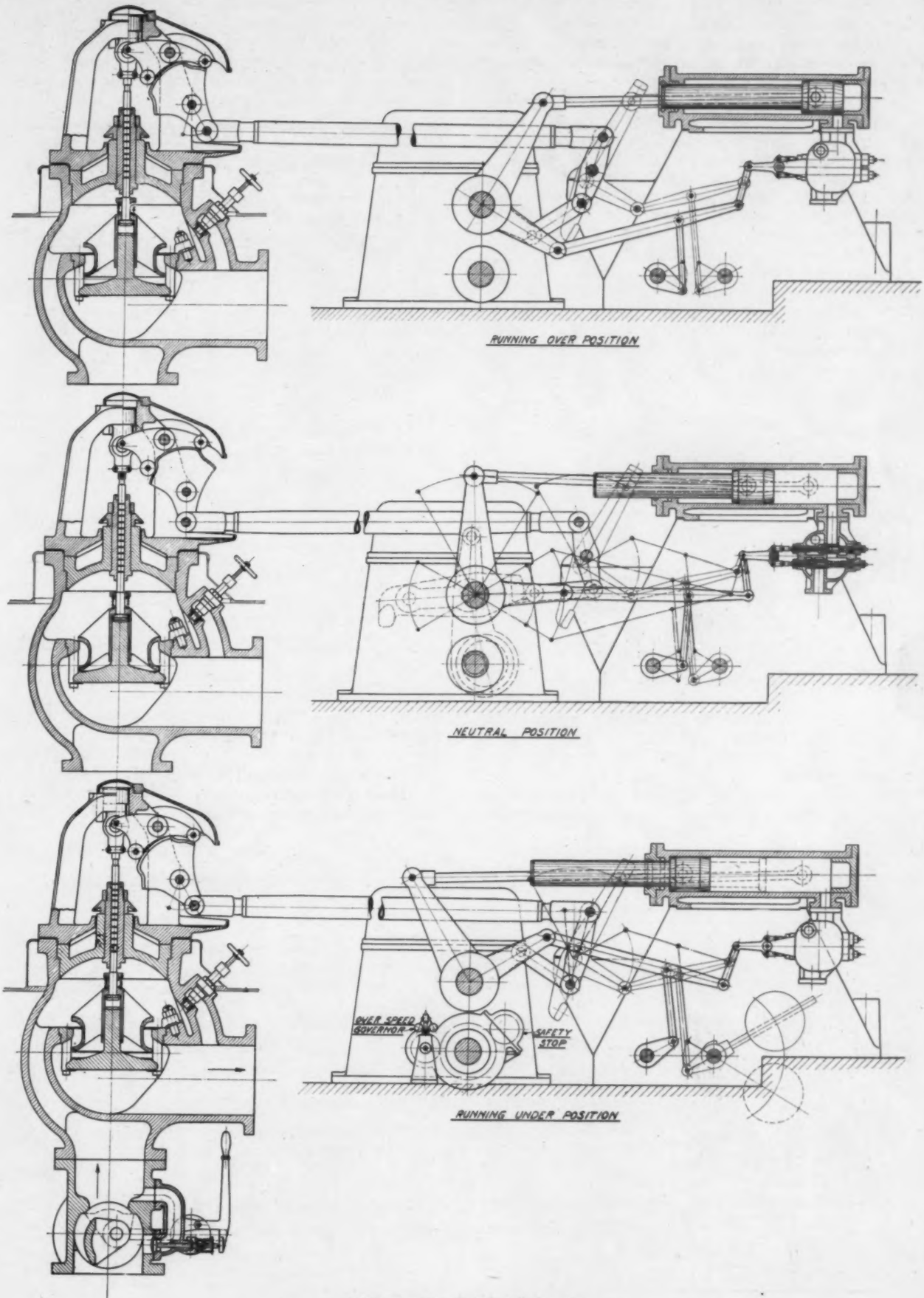


FIG. 24—Reversing Mechanism

actuated from the reversing gear mechanism. From this valve the steam reaches the different cylinders through horizontal steam pipes, fitted with expansion joints.

All the running parts of the engine are supplied with oil under pressure from a large overhead tank. The oil is introduced in the end of the crankshaft and flows through the drillings into circular grooves in the main bearings and crankpin shells and reaches through the hollow connecting rods, the wrist pins and crosshead shoes. A second lead connects to the end of the hollow layshaft from where every bearing, pin and link of the reversing gear is supplied with oil under pressure. The oil used on the engine is drained into the crankpit and flows by gravity to a filter from where it is pumped back to the overhead tank.

This forced feed lubrication has shown remarkable results in reducing the friction and wear, its absolute reliability and its simplicity have more than justified the initial cost, and its use allows a simpler and stiffer construction than would otherwise be possible.

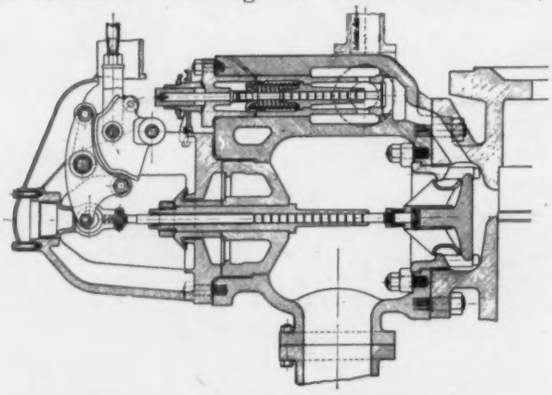


FIG. 25—Auxiliary Exhaust Valves.

It is interesting to record, that it has not been necessary to take up on the main bearings crank pin, wrist pin and crosshead shoes, since the engine has commenced operating in January, 1924.

The condensers attached to the engine are interesting, in that they are somewhat different in design than the usual condenser in use with a steel plant engine. These condensers, Fig. 28, were designed to take care of large pulsations of steam and still maintain a satisfactory vacuum and at the same time use a constant flow of water economically.

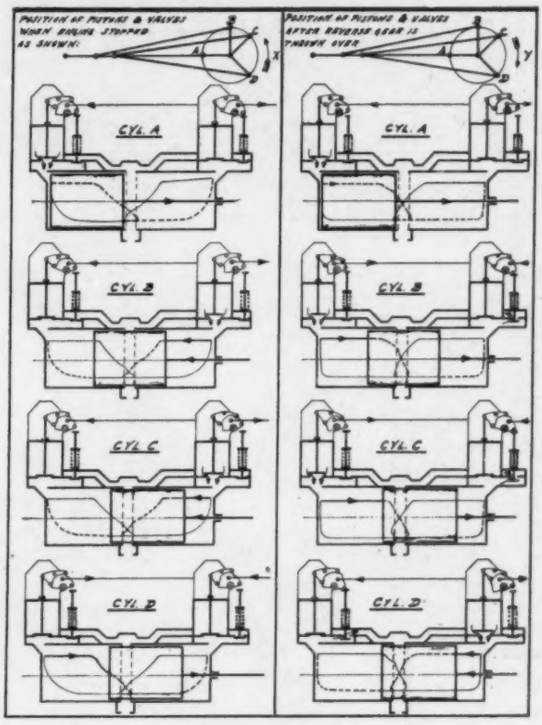


FIG. 26—Valve Gear

The condensers proper, which operate on the barometric principle, are built up of a large cast iron

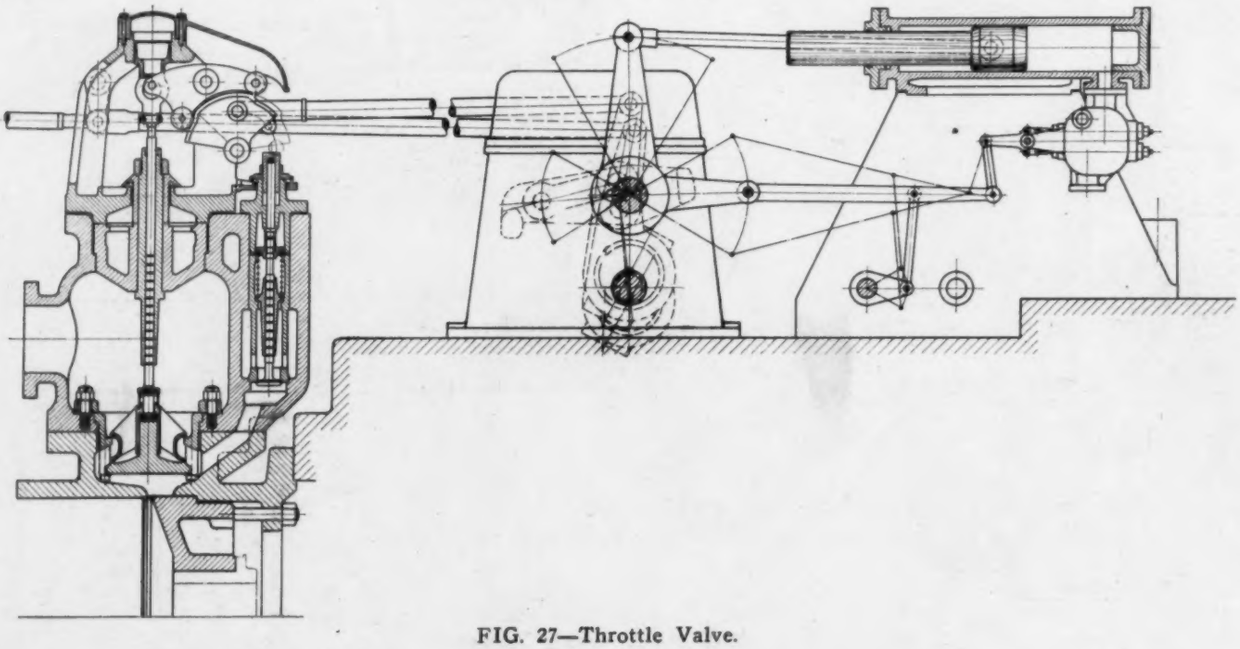


FIG. 27—Throttle Valve.

shell about 10′-0″ in diameter and 22′-0″ in length, and the inside of the condenser is constructed with a number of trays so designed as to hold considerable water in storage on its path through the condenser, so that there is ample surface and volume exposed to take care of the sudden fluctuations in the volume of steam coming to the condenser.

The vacuum pumps in connection with the engines and the condensers are also of the uniflow design, having uniflow suction ports and spring discharge values, there being no suction valves on the machine, are all of the same size and type and driven by ordinary piston valve steam engines, the speed being controlled by throttling governors.

Engine Operation. ....

For some time after the engines were installed we experienced operating difficulties, and these have no doubt been exaggerated but they nevertheless retarded production until corrected.

Some of these difficulties are enumerated as follows: trouble with oiling system, due to improper filteration; the engines were shut for a few days after we started to operate to check bearing alignment. The hydraulic control cylinder on the reversing engine broke and had to be replaced and a hydraulic shock absorber installed. Two cylinders on the continuous mill engine cracked, being scored by the cast iron sleeves between the pistons rubbing against the cylinder walls, This was caused by local overheating and resulting distortion of the piston rods, the metallic rod packing became fouled due to extremely high temperatures and foreign matter carried over by the steam soon after the new boiler plant was put in operation. One-eighth inch was taken off the diameter of the pistons and further trouble from the source avoided.

It is also interesting to note that the 19″ mill engine ran with three cylinders operating during the time we were encountering these troubles, and as the head was taken off the cylinder from which the piston was removed we were able to note that the balanced poppet valves were absolutely steam tight; other troubles met with were of a more minor nature, and have since been overcome and the engines are now operating to the entire satisfaction of the Company, handling all types of load easily and are by no means the "Neck of the Bottle" in the mill operations and possible output.

The following data is taken from the engine builder's estimate of the performance of the reversing blooming mill engine.

The Nordberg Company in their contract estimated that with steam pressure of 240 lbs. gauge and 125° F. superheat, the 35″ mill engine with the air pump would consume approximately 280 lbs. of steam per net ton of steel rolled, reducing an 8,300 lbs., 19″ x 26″ ingot to 11 elongations rolling, at the rate of 100 net tons per hour.

The following is the estimate of steam consumption as submitted by the engine builder:

Assumed rolling work per ton and 11 elongations.....	23,000,000	Ft. Lbs.
Rolling work per ingot.....	84,800,000	" "
Friction work " "	13,500,000	" "
Acceleration work per ingot...	34,500,000	" "
Total work per ingot	132,800,000	" "
Total work per ingot I.H.P. H.P....	67	I.H.P. Hr.
Number of working turns.....	51	
Work per turn	2,605,000	Ft. Lbs.

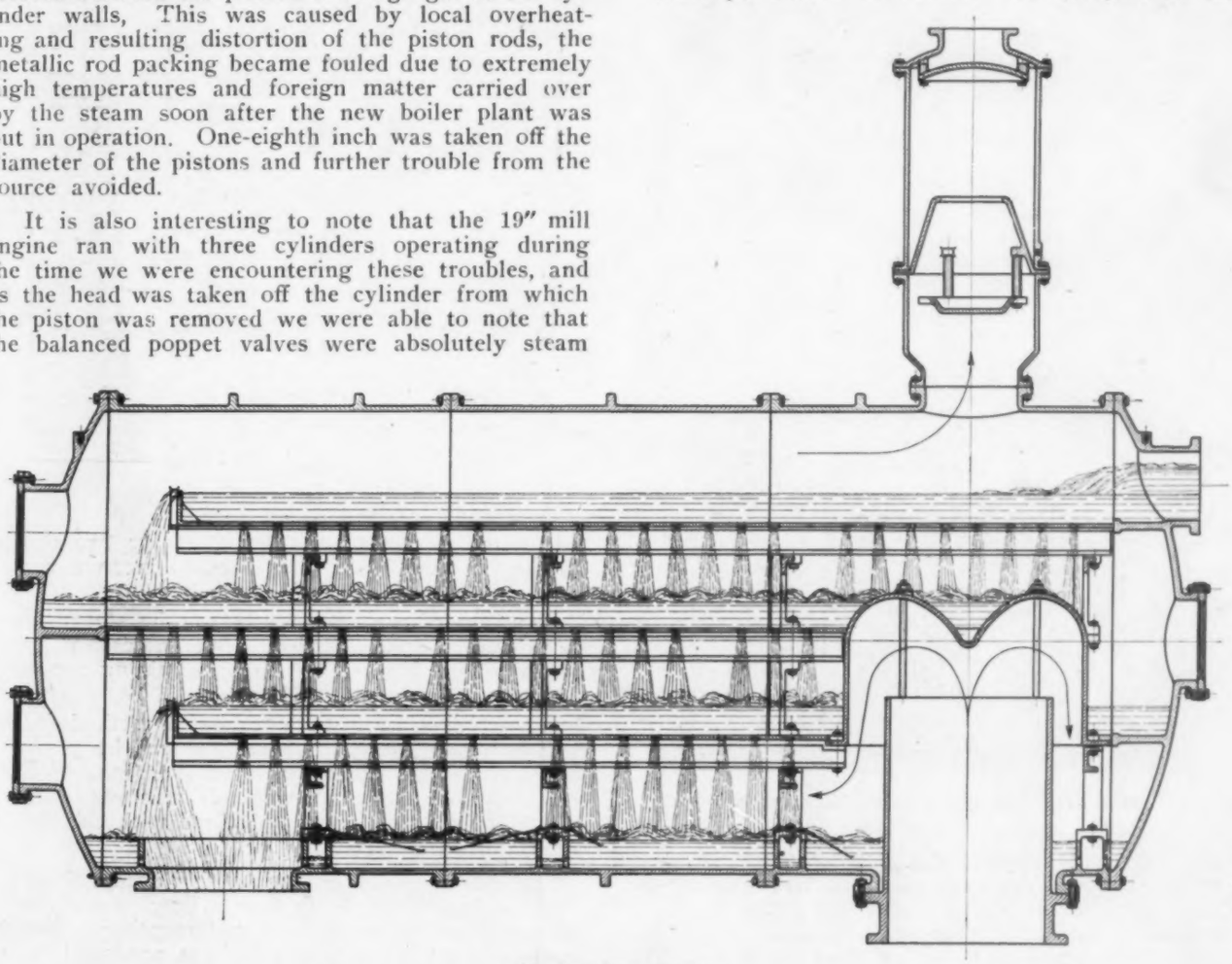


FIG. 28—Condensers.

Steam consumed per 1,000,000 ft. lbs. when realizing 69 M.E.P. out of 87 M.E.P. available	6.97	lbs.
Steam for working turns	925	"

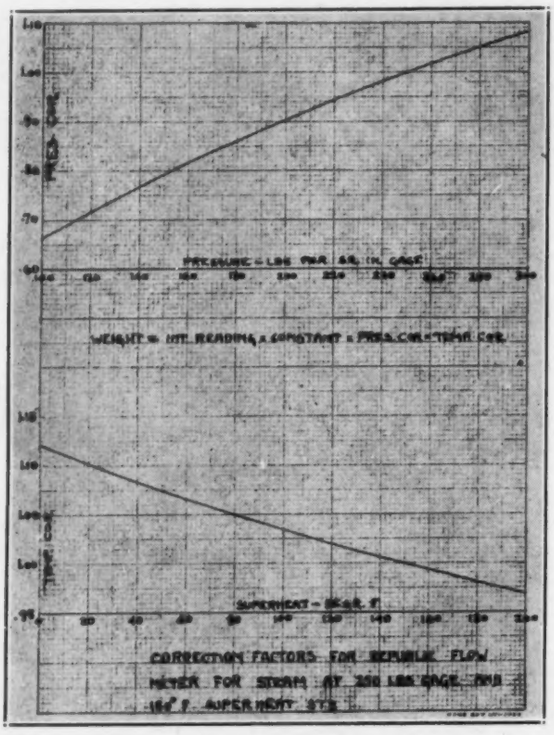

PRESSURE - LBS PER SQ. IN. GAGE
WEIGHT = INT. READING x CONSTANT = PRES. CORR. TEMP. CORR.
SUPERHEAT - DEG. F.
CORRECTION FACTORS FOR REPUBLIC FLOW METER FOR STEAM AT 250 LBS GAGE AND 150° F SUPERHEAT STEAM

FIG. 29—Republic Corrective Curve.

Steam working in cylinder during plugging 735 lbs. not charged, but condensation for same	147	lbs.
Used for plugging due to lead	14	"
Condensation for same	4	"
Steam consumed per ingot by engine	1,089	"
For auxiliaries, etc.	75	"
Total steam consumed per ingot	1,164	"

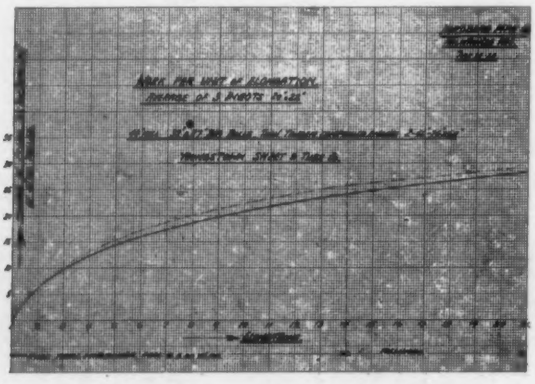


FIG. 30—Work per Unit of Elongation.

Total steam consumed per gross ton steel rolled	315	lbs.
Total steam consumed per net ton steel rolled	280	"
Steam consumed per I.H.P. hour of main engine	16.3	"

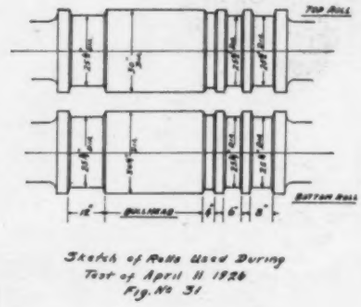
Allowed for reversing, plugging and throttling over standard non-reversing uniflow engine	44%
For plugging only 164 lbs, or	15%
For throttling only	29%

The size of the sheet bar ingot, however, has since been changed to a 9,300 lbs. 22" x 24" ingot. Fig. 31 shows the rolls as used during the test.

The heat rejection method is the one usually accepted for determining the steam consumption of a prime mover. Unfortunately in this installation it was not practical to use this method. The engines have barometric condensers as already described and there is such a small rise in the temperature of the

The Average Dimensions of Passes, Reduction and Elongation of the 15 Ingots Rolled During Test - April 11-1926.

Pass No.	Dimension of Pass - Inches	Draft	Area	Reduction Sq.In.	%	Length after Pass	Elongation Per Pass	Per Inch	Roll Dia. Inch	Rolling Turns
Ingot	23½ x 21⅝		505.25			6.525				
1	21½ x 21⅝	2	462.5	42.75	8.46	71.3	6.05	1.09	30¼	.75
2	20 x 21⅝	1½	430.	32.5	7.02	76.8	5.5	1.18	30¼	.81
3	19 x 21⅝	1	408.5	21.5	5.00	80.8	4.0	1.24	30¼	.85
4	16¾ x 21⅝	2¼	360.	48.5	11.85	91.7	10.9	1.41	30¼	.97
5	14¼ x 21⅝	2½	306.5	53.5	14.85	107.5	15.8	1.65	30¼	1.13
6	12¼ x 21⅝	2	263.5	43.0	14.0	125.1	17.6	1.92	30¼	1.32
Turn	12" Pass									
7	19¼ x 12¼	2¼	236.0	27.5	10.4	139.5	14.4	2.14	25¾	1.72
8	16⅝ x 12¼	2⅝	202.5	33.5	14.2	163.0	23.5	2.50	25¾	2.02
9	14⅝ x 12¼	2	177.5	25.0	12.3	185.5	22.5	2.84	25¾	2.29
10	11⅞ x 12¼	2⅝	144.0	33.5	18.9	229.0	43.5	3.51	25¾	2.83
11	11 x 12¼	⅞	134.7	9.3	6.45	245.0	16.0	3.76	25¾	3.02
12	9 x 12¼	2	110.25	24.45	18.2	298.0	54.0	4.58	25¾	3.69
Turn	B.H.									
13	7 x 12¼	2	85.75	24.5	22.2	385.0	86.0	5.90	30¼	4.05
14	6¼ x 12¼	⅞	76.6	9.15	10.7	431.0	46.0	6.60	30¼	4.53
Turn	6" Pass									
15	11 x 6¼	1⅝	68.75	7.85	10.2	480.0	49.0	7.35	25¾	5.93
16	9⅜ x 6¼	1⅜	61.0	7.75	11.25	541.0	61.0	8.30	25¾	6.68
Turn	B.H.									
17	4⅞ x 9¾	1½	46.3	14.7	24.1	712.0	171.0	10.90	30¼	7.59
								Total		50.09



Sketch of Rolls Used During Test of April 11 1926 Fig. No 31

FIG. 31—Roll Design.

injection water that an error of one or two degrees in the observed temperature would mean a serious error in the results.

Because of the arrangement of the steam piping, it was not possible to isolate the necessary boilers for supplying the engine and determining the steam supply by weighing the feedwater.

Consequently, the only practical method for determining the steam consumption was by means of a meter in the steam line to the engine. For this service, a Republic Flow Meter was used because of the satisfactory results obtained with this type of meter during the last few years. Fig. 29.

It has come to be a generally accepted opinion that it is impossible to use a flow meter for the measurement of steam to a reciprocating engine because the pulsating flow of steam produced by the reciprocating unit will usually cause any flow meter

to give a high reading. This conclusion is based upon experience with simple, cross compound and duplex engines.

In the case under consideration, the engine consists of four double acting cylinders, all taking steam direct and exhausting to the condenser, in other words, a quadruplex engine. With this number of impulses per revolution, the steam demand would be almost constant and very little pulsations would be expected.

There is a large receiver at the engine and the orifice has been placed fully 150 feet ahead of this receiver. In addition, there are two dampening orifices between the meter orifice and the receiver. There is no question but that the results obtained in this installation are reasonably accurate as they checked closely with the horse power integrators of the Maihak indicators which were used during several of the tests. Fig. 30.

The following tabulation is the result of a test run on April 11, 1926, the material at this time approaching very closely to the specified conditions given by the engine builders, namely 11 elongations.

PERFORMANCE OF THE ENGINE.

Date of test ---------- April 11, 1926.
Time of test ---------- 8:08 p. m. to 8:39-30 p. m.
Duration of test ---------- 31.5 Minutes

ENGINE DATA

1. Builder ---------- Nordberg Manufacturing Company
2. Type ------ 4 Cylinder Poppet Valve Reversing Uniflow
3. Bore of cylinder ---------- 36 inches
4. Length of stroke ---------- 60 inches
5. Diameter of piston rods ---------- 10 inches

STEAM CONDITIONS

6. Average steam pressure at flow meter lbs. gauge 238
7. Average steam temperature at flow meter °F---- 552
8. Average superheat at flow meter °F---------- 150
9. Average steam pressure at the engine lbs. gauge 217.3
10. Average steam temperature at the engine °F---- 541.5
11. Average superheat at the engine °F ---------- 147
12. Vacuum inches mercury---------- 25.5
13. Barometer inches mercury ---------- 29.5

STEAM MEASUREMENTS BY METER

14. Steam used during test by Rep. Flow Meters lbs. 22,800
15. Average reading in per cent of scale on Rep. Meter 30
16. Orifice constant fur. by Republic Flow Meter Co. 670
17. Correction factor for steam temperature (Rep) 1.00
18. Correction factor for steam pressure (Republic) .973
19. Total steam during test after correction for temperature and pressure at meter, lbs. ---------- 22,184
20. Steam per net ton of steel rolled 217.3 lbs., 147° F. Superheat, lbs. ---------- 318
21. Steam per net ton of steel rolled 240 lbs., 125° F. Superheat, lbs. ---------- 317
22. Rate of rolling during test net tons per hour---- 133

Test started 8:08 p. m. Test completed 8:39:30 p. m.
Night Turn, April 11, 1926.

Number Ingots Rolled	Size of Ingots Rolled	Weight	Rolling Time Per Ingot Seconds	Total Time Of Actual Rolling	Size of Bar In Inches
1	22 x 24	9,300	75	28.0	4.75 x 9.75
2	"	"	81	25.6	" "
3	"	" Cobble	142	27.8	" "
4	"	"	117	27.2	" "
5	"	"	105	27.8	" "
6	"	"	114	29.0	" "
7	"	"	90	25.8	" "
8	"	"	89	26.6	" "
9	"	"	101	25.4	" "
10	"	"	99	26.2	" "
11	"	"	86	25.4	" "
12	"	"	93	25.6	" "
13	"	"	96	26.4	" "
14	"	"	109	29.6	" "
15	"	"	93	26.2	" "
TOTAL		139,500	1,490	402.6	

Total rolling time 24 Minutes 50 seconds
Total time of test 31 Minutes 30 seconds
Time not rolling 6 Minutes 40 seconds

Total weight of material rolled, $\frac{9300 \times 15}{2000} = 69.75$ Net Tons

Average interval between ingots ---------- 28.6 seconds
Average cross section of ingots ---------- 505.25 sq. inch
Average cross section of bar ---------- 46.31 sq. inches
Average enlongations ---------- 10.9

Average maximum R.P.M. of engine during each pass of the 15 ingots rolled during the test period:

Pass. No.	1	2	3	4	5	6	7	8	9	10	11	12
Max. R.P.M. eng.	82	121	86	120	88	111	103	108	108	112	114	125

Pass. No.	13	14	15	16	17
Max. R.P.M. engine	131	147	150	160	159

Average number of turns of engine per ingot 120.

Test Started 8:08 P. M. Test Completed 8:39-30 P. M. Night Turn April 11, 1926

ROLLING TIME OF EACH INGOT
INGOT NO.

Pass No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Seconds														
1	1.0	.6	.4	.5	.6	.6	.6	.6	.4	1.0	.6	.4	.4	.4	.4
2	.6	1.0	.4	.5	.4	.6	.5	.6	.5	.6	.5	.4	.4	1.0	1.0
3	.5	.5	1.0	.5	.6	.6	.6	.6	.6	.6	.5	.6	1.0	.4	.6
4	.5	1.2	1.2	1.0	1.2	1.0	1.0	1.2	1.0	.5	1.2	1.0	1.0	1.4	.5
5	1.0	1.0	1.2	.5	1.0	.5	1.0	1.0	1.0	.5	.5	.5	1.0	1.0	1.0
6	1.2	1.2	1.0	1.2	1.4	1.4	1.2	1.2	1.4	1.2	1.2	1.2	1.2	1.2	1.2
7	1.6	1.4	1.0	1.2	1.0	1.2	1.0	1.2	1.2	1.2	1.0	1.0	1.2	1.2	1.4
8	1.0	1.2	1.2	1.8	1.6	1.6	1.2	1.0	1.4	1.4	1.2	1.4	1.8	1.2	1.2
9	1.6	1.4	1.0	1.2	1.4	1.6	1.4	1.2	1.6	1.4	1.0	1.2	1.2	1.6	1.2
10	1.8	1.4	1.4	1.4	2.0	2.0	2.0	1.8	1.8	2.0	1.8	1.6	1.6	1.4	1.6
11	1.8	1.6	2.0	2.0	1.6	2.0	1.4	1.4	1.6	2.0	1.6	1.4	2.0	1.8	1.8
12	1.2	1.2	2.0	2.0	2.0	2.2	1.8	1.8	1.6	2.2	2.0	1.8	2.0	2.2	1.6
13	1.8	1.8	2.0	2.2	2.0	2.0	2.0	2.0	1.6	2.0	2.0	2.0	2.6	2.0	1.8
14	1.8	1.6	1.8	1.2	2.2	2.4	1.6	1.6	1.6	1.8	1.8	2.0	1.8	2.4	1.8
15	3.0	3.0	3.0	2.6	3.0	2.6	2.6	2.6	2.6	2.0	2.0	2.6	3.0	3.0	2.8
16	3.0	3.0	3.2	2.8	2.8	3.4	3.0	3.0	3.2	2.8	3.0	3.0	3.0	3.8	2.8
17	3.8	3.4	4.0	3.8	3.0	3.0	3.2	4.0	3.2	3.0	3.6	3.4	3.0	3.6	3.4
	27.8	26.8	27.8	27.0	27.8	29.0	26.4	26.8	26.6	26.7	26.2	26.2	27.6	29.6	26.4

The following data refers to a test run on November 20, 1925, and clearly illustrates the losses due to a variable rolling schedule:

Test Started 7:53 P. M. Test Completed 8:55-30 P. M. Night Turn—November 20, 1925

Ingot No.	Size of Ingot in Inches	Weight Lbs.	Actual Rolling Time	Bar Size in Inches
1	21.5x23.5	9,300	134 seconds	5.0x9.75
2	"	"	87 "	"
3	"	"	89 "	"
4	"	"	93 "	"
5	"	"	98 "	"
6	"	"	95 "	"
7	"	"	99 "	"
8	"	"	100 "	"
9	"	"	115 "	3.25x9.5
10	"	"	103 "	"
11	"	"	138 "	"
12	"	"	105 "	"
13	"	"	147 "	"
14	"	"	99 "	5.0x9.75
15	"	"	124 "	"
16	"	"	123 "	"
17	"	"	93 "	"
18	"	"	83 "	"
19	"	"	94 "	"
20	"	"	89 "	"
21	"	"	83	"
22	"	"	115 "	3.25x9.5
23	"	"	112 "	"
24	"	8,400	120 "	2.0x16.0
25	"	9,300	115 "	5.0x9.75
26	"	8,400	127 "	2.0x16.0
27	"	"	124 "	"
28	"	"	126 "	"
29	"	9,300	102 "	5.0x9.75
30	"	"	92 "	"
			3,224	

Total time of test	62 minutes 30 seconds
Total rolling time	53 minutes 44 seconds
Time not rolling	8 minutes 46 seconds
Total weight of material rolled $\frac{26\times9300+4+8400}{2000}$	=137.7 net tons
Average interval between ingots	17.5 seconds
Average cross section of ingots	505.25 sq. in.
Average cross scetion of bar	40.7 sq. in.
Average elongations	12.41
Flow Meter readings corrected for pressure and temp.	51,362 lbs.
Steam consumption per net ton $\frac{51362}{137.7}$	= 373 lbs.
Deduction for excess elongations $373 \times \frac{11}{\sqrt{12.41}}$	= .9415 × 373 = 351 lbs.

The above data shows that the engine, together with the air pump, consumed 317 lbs. of steam per net ton of steel rolled.

The steel rolled during the test was of uniform temperature and with the exception of the cobble made on the third ingot, everything was in favor of representative conditions for a commercial test.

A glance at the time in seconds per ingot rolled shows the variations to be great, while a study of

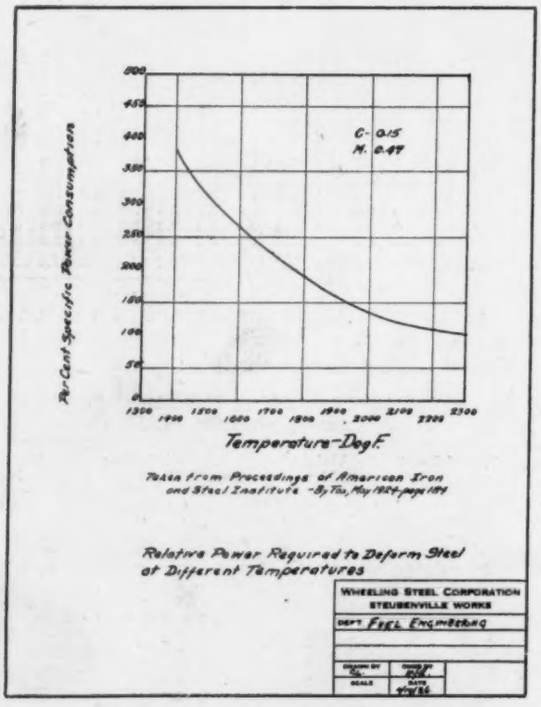

Per Cent Specific Power Consumption
C- 0.15
M. 0.47
Temperature-Deg F.
Taken from Proceedings of American Iron and Steel Institute - By Tao, May 1924 page 189
Relative Power Required to Deform Steel at Different Temperatures
WHEELING STEEL CORPORATION
STEUBENVILLE WORKS
DEPT. Fuel Engineering

FIG. 32—% Power Required to Deform Steel at Different Temperatures.

the table showing the actual time the ingots were engaged in the rolls to vary very little, which points to the necessity for more study on the manipulation of the ingot and the time of approach to the mill.

In the above test the steel was not of the same uniform temperature as was the case in the test run on April 11, 1926.

A study of the graph Fig. 32 will show the effect of temperature variations on the power consumption.

While the steam consumption data given in these tests compares very favorably with some of the electric-driven mills, the results are given as a comparison with the performance of the modern steam-driven units.

Power Engines

The current for driving the mill auxiliaries is supplied by two 1000 K.W. D.C. General Electric generators, driven by two 24x40 Nordberg Duplex Uniflow condensing engines, running at 150 R.P.M. These engines are supplied with steam from the same system as the mill engines and exhaust into a

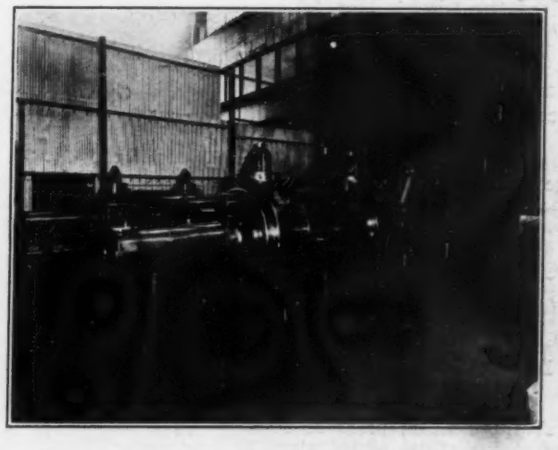


FIG. 33—Nordberg Power Engine.

barometric condenser served by an air pump of the same design as those for the larger units. Fig. 33.

They are of the straight uniflow type, having no auxiliary exhaust valves. The steam is admitted to the cylinders by double beat, balanced poppet valves, which are positively opened and closed by oscillating cams operated from eccentrics on the layshaft, no springs or dashpots being required. Each valve has its own eccentrics and cam and can be adjusted independently.

The cutoff is under control of an inertia and centrifugal governor mounted on the gear-driven layshaft between the two eccentrics. Should, due to lack of vacuum, the compression rise too high, relief valves will permit the steam in the cylinder to flow back into the steam pipe.

The pistons are of the full floating type, being carried by the crossheads and tailshoes, equipped with snap rings and steam-tight keepers.

The engines are dependable and operate economically.

In conclusion, I wish to thank those who criticized the text and helped in the collection of the data, thereby making the presentation of the paper possible.

Yard Switching and Mill Transportation

By W. B. POTTER* and G. H. SHAPTER†

THE transportation of material is one of the essential requirements of manufacture. It enters into the various processes throughout the entire production, including receipt of the raw material and delivery of the finished product. It is a non-productive process involving time and expense and therefore is a subject worthy of careful study in its relation to the particular conditions of manufacture. A steel plant probably has as great a diversity with a heavier class of transportation than any other industry, and it is clearly a place where motive power can best serve the purpose.

The distinction between yard switching and mill transportation is more in kind than in fact, the difference being that switching deals principally with freight cars, while mill transportation includes a variety and oft times special type of equipment.

The same kind of motive power may not be as advantageously applicable to all conditions, and there are quite a number of different kinds from which to make a selection. To enumerate, the following list mentions the more important varieties of motive power that may be considered:

Independent Units: Steam, gas mechanical, oil electric, gas electric, storage battery with engine auxiliary.

Station Charged Units: Compressed air, supercharged water, storage battery.

Trolley or Third Rail Units: Electric, electric with storage battery auxiliary.

It has been suggested that this general class of transportation be covered under the separate headings.

Yard Switching

This service is characterized by short movements and with considerable time lost for coupling and at switches. From observed operations the time in motion may be assumed as one-half to one-third of the time in service. While the maximum speed may be ten miles an hour or more, the average speed is much less and the schedule speed will usually be found around three miles per hour or about one-half the six miles per hour which is the conventional schedule commonly assumed. The motive power for this switching service should provide rapid acceleration, be equipped for quick reversal and in general should have the characteristic which may be described by the word "lively." The maintenance of the locomotive is a feature affecting its usefulness both as to the cost of upkeep and the time it is laid up for repairs. There is often a limited motive power reserve for yard service, hence the availability, as it is often called, or the number of hours per year during which the locomotive is available for service, may have an important bearing on the investment for motive power and cost of operation.

The average power requirement for yard switching is considerably less than is sometimes appreciated. While the tractive requirements are high the schedule speed is so low that the average power performing the schedule may range from 30 to 60 kw. and more often will be nearer the lower figure. The maximum and average power while in motion will be considerably higher than these figures, depending upon the acceleration. The power requirement for switching may be illustratd by the following calculatd table for a 50-ton locomotive switching a 200-ton trailing train on level track with 18% coefficient of adhesion during acceleration and braking at one-half mile per hour per second.

Length of Run Ft.	Average Speed in Motion M.P.Hr.	Schedule Speed M.P.Hr.	Watt-Hr. per Ton Mile	Average Kw.
150	3.7	2.2	85	46.5
300	5	3	64	48
500	6.1	3.65	52	47.5
750	6.9	4.1	44	45
1000	7.3	4.45	40	44
1500	7.8	4.8	36	43

The steam locomotive is so generally used and has been so successful in switching service that there should be some good reason for considering other types of motive power. Expediting the switching movements, more hours available for service, lesser number of locomotives needed, lower maintenance, reduction in cost of fuel and the elimination of smoke, are some of the reasons which justify this consideration.

The gasoline mechanical locomotive has a type of drive which is not suitable for the high tractive effort and rapid acceleration essential to the proper handling of yard switching. The shifting of gears interrupts the continuity of the tractive effort and duty on the clutch would be very severe. Locomotives of this type have proven successful in handling light service as in the easier duty of mill transportation.

The Diesel or oil electric locomotive is a comparatively new type of motive power in so far as its application to regular service. It is really a further development of the gas electric car, a number of which have been in service for some 15 years. In effect, it is an electric locomotive deriving its power from an oil engine located in the cab instead of from a trolley wire or third rail. Oil engines designed for general purposes are usually too large and heavy for installation on a locomotive, which in most cases will necessitate a special design to keep within the limitations of weight and space.

The oil engine has the highest fuel economy of any prime mover in general use and this holds true with engines of relatively small power. As an illustration, the 300 h.p. Ingersoll-Rand engine will deliver a brake horsepower hour at full load with a fuel consumption of .43 lb. of oil. Including the generator losses, this means the generation of a kilowatt hour electrical output for about 12,000 B.t.u. It will be appreciated that this performance has hardly been obtained as yet with even the best of modern steam power stations. The performance of this engine during switching service is of more interest however, than its full load fuel economy. The record from several weeks' operation at a load factor of about 15 per cent gave an electrical output of 6.3 kw-hr. per gallon of oil, or about 21,500

†Engr., General Electric Co., Schenectady, N. Y.
*Engr., General Electric Co., Schenectady, N. Y.

B.t.u. per kw-hr. This, compared with about 11 kw-hr. per gallon of oil at full load is a good example of the excellent performance of an oil engine under widely varying load.

The speed and torque requirements of a locomotive are so variable that to properly utilize an oil or gasoline engine, some means must be provided for

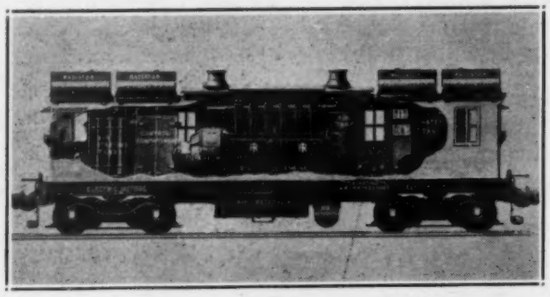


FIG. 1—Sectional view of 60 ton oil electric locomotive showing location of engine, generators, motors and other equipment.

changing the torque between the engine shaft and driving wheels. As the torque of such engines has a definite limit the engine would be of prohibitive size unless some means is provided that will be equivalent to a changeable gear ratio. While mechanical transmission with its different gear ratios is successful for small powers, it is not well suited to the greater power and torque required in yard switching. The success of electric equipment for transportation has been thoroughly demonstrated through many years of experience.

The electric drive as used with the oil engine comprises a direct current generator supplying current to the motors of the type commonly used on electric locomotives. Variation in the speed and torque of the driving wheels is smoothly accomplished throughout the required range by simply varying the voltage of the generator. An easily operated electric reversing switch provides for the directional movement of the locomotives.

Freight yard switching is being successfully handled with 60-ton locomotives equipped with 300-h.p. engines. Although 300 h.p. is considerably less than the power rating of steam locomotives used in this kind of switching, it appears that these oil electric locomotives handle the switching more expeditiously than do the steam locomotives having equal weight on drivers. The larger powered steam locomotives could maintain a greater tractive effort at higher speed than the oil electric, but where this higher speed serves no purpose the higher tractive effort of the oil electric locomotive within the speeds required for switching gives it an advantage.

The relative fuel consumption of oil electric and steam locomotives in switching service can perhaps best be given by comparing the gallons of oil with the tons of coal. The records obtained indicate that 20 to 25 gal. of oil are equivalent to a ton of coal so that with oil at 5c a gallon, the comparative cost of fuel on this basis would balance at $1.00 to $1.25 per ton for coal. As the oil engine and the electrical equipment are composed of relatively small parts easy to handle, and there being no boiler to overhaul, the maintenance of an oil electric switcher may reasonably be assumed as one-half the cost of maintaining an equivalent steam locomotive.

The gas electric locomotive is similar to the oil-electric except as to the type of engine and character of fuel. The electric drive is advantageous with the gas electric for the same reasons mentioned for the oil electric. This locomotive is somewhat less expensive because of the lower cost of the power plant equipment, but the fuel expense is increased because of its higher cost per gallon and the lower fuel economy of the gasoline engine. The quantity of fuel for a given service will be from one-half to two-thirds more than for an oil engine, which with the ratio of three to one for the relative cost per gallon, means a difference in fuel cost of about five to one. Improvements in carburetors will presumably lead to the successful use of a cheaper grade of fuel which will correspondingly decrease this ratio of fuel cost.

The storage battery locomotive with engine auxiliary is a combination in which a gasoline or oil engine, of sufficient power to provide the average demand, maintains the charge in the battery. The battery serves as reservoir of energy delivering power at intervals whenever the demand exceeds the output of the engine. The power supplied by the engine further permits a reduction in the amount of battery required. There are places where the storage battery locomotive will best serve the purpose, but where it may be inconvenient to take it out of service for the purpose of charging. Where an independent battery unit will best meet the requirements, an engine auxiliary combination will provide for this continuity of service.

The compressed air locomotive is more suitable for mill transportation than the heavier duty of yard switching. As it is a simple machine which can be quickly recharged it is well worthy of consideration where it can be advantageously used. It required a suitable charging plant and its fuel economy is

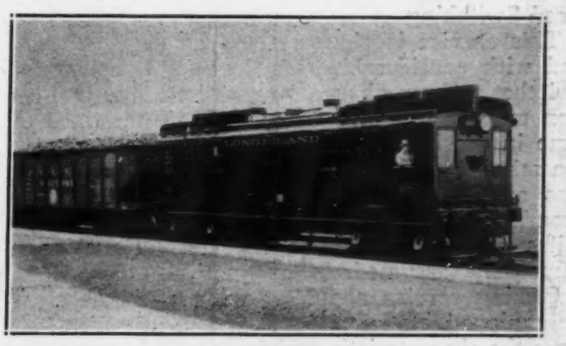


FIG. 2—100 ton oil electric locomotive equiped with two 300 h.p. Ingersoll-Rand engines and four 200 h.p. motors operated by the Long Island Railroad Company.

rather low. As a type of motive power its application will presumably be limited to relatively small locomotives.

The super-charged water locomotive is similar in some respects to the compressed air locomotive and is likewise limited in its effective application.

The storage battery locomotive may well be regarded as best of the station charged units. It is fully capable of handling yard switching and is as responsive to the demand as any electric motor locomotive. Its duty cycle is necessarily limited however to the amount of battery provided. Where the battery is adequate the performance is very satisfac-

tory, but like all station charged locomotives it must receive more energy than it delivers. Where it can conveniently be done, it is advantageous to charge the battery at intervals whenever the locomotive is idle, but it is more often found expedient to take the locomotive out of service and place it on charge for a number of hours. Including the losses in the charging equipment usually required, the overall electrical efficiency will not be far from 55 per cent. The life

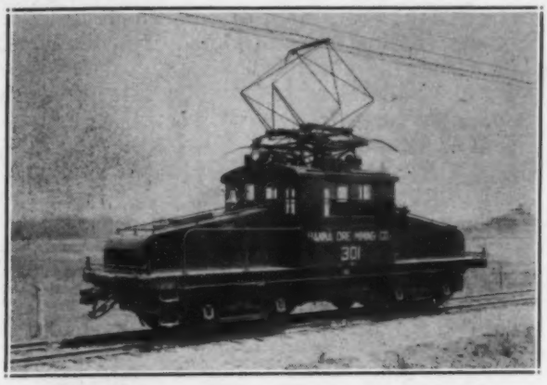


FIG. 3—60 ton 600 volt direct current locomotive equipped with pantograph and side collectors operated by the Hanna Ore Mining Company in the Wabigon Pit at Buhl, Minn.

of the battery being three to four years, its renewal becomes an appreciable item of maintenance in this type of locomotive.

The electric locomotive, whether deriving its power from a trolley or third rail, is unquestionably the most powerful type of locomotive that may be used, and is the most effective of all to expedite switching movements. Its tractive power is limited as in all cases by the weight on drivers, but the speed at which this tractive power may be obtained is only a question of motor capacity. As the power is derived from a central station it is practically unlimited so far as the locomotive is concerned. The maintenance of an electric locomotive is the least of any of the types mentioned, and may be assumed as about one-third of a corresponding steam locomotive. These locomotives require a contact system throughout their range of operation and a power supply of suitable voltage. Either an overhead trolley construction or third rail may be used with equal success, so far as delivering the power. The choice as to which should be used is wholly dependent upon the local conditions.

Whether to use electric locomotives or some other form of independent unit may in some cases be easily decided because of objections to either the trolley or third rail. Where these objections do not exist it then becomes a question of the relative initial expense and cost of operation. The greater the number of motive power units in respect to the aggregate length of track over which they operate, the more it will favor the electric locomotive.

The electric locomotive with storage battery auxiliary provides a means for entering upon certain tracks as within buildings where a trolley or third rail would not be permissible. The storage battery receives its charge while the locomotive is taking its power from the trolley, and so is in condition to supply power whenever it is needed. A comparatively small battery will usually be sufficient for this purpose.

Mill Transportation.

As distinct from yard switching, which involves the handling of the regular freight cars, the transportation problem about a steel mill involves the handling of material in many special ways. In these special applications the locomotive or locomotives used are required to be in service practically twenty-four hours a day and are confined in their service to the particular application for which they have been designed.

These special service locomotives operate on various track gauges, sometimes as small as 18 in., and up to standard railway gauge of 56 1-2 in. There are a great many places in the steel mill yards where the track was located, when the plant was built, without much consideration being given to the track gauge as space seemed to be at a premium. Consequently there are a great many narrow gauge industrial tracks, which have very sharp curves, small clearances in buildings, doorways, etc., such as to prohibit the installation of electric locomotives requiring space for trolley wires, third rails or batteries.

The original method of handling the transportation on these different tracks was by the use of specially designed narrow gauge dinkey steam locomotives. It is, therefore, apparent that when electric installation is desired, the type and design of the locomotive involve very many special considerations as to width, wheel base, clearance, overhang and weight.

Following is given a brief description of some of the more common applications for electric and storage battery locomotives in steel mill service.

The by-product coke oven is a comparatively recent development which includes all the operation through which coal goes when introduced into the ovens until it is finally placed on the cooling wharf. An electric locomotive is particularly well suited to meet the special requirements for handling this coke. The usual type of coke oven locomotive is a 20-ton

FIG. 4—40 ton combination trolley and storage battery locomotive operating in the Pittsfield works of the General Electric Company.

single truck machine especially designed with respect to the location of the operator. The operator is in an elevated cab where he has a clear view of all the operations which this locomotive must perform. This position enables him to spot the cars or move slowly while the hot coke is being pushed out of the ovens into the coke quenching car. It affords him an easy means of reaching the water valve when the cars are placed in the quenching tower and a view of the coke wharf when he dumps the coke from the cars.

This kind of locomotive is usually equipped with a 100 cu. ft. air compressor, as air is not only required for handling the train, but also for operating the coke quenching car doors. An ordinary coke car weighs approximately 70 tons loaded. The round trip operating cycle per locomotive varies, depending upon the particular design of the coke plant, but the run for the locomotive rarely exceeds 500 ft. for any individual movement. The round trip from the ovens to the quenching tower or the coke wharf and back to the

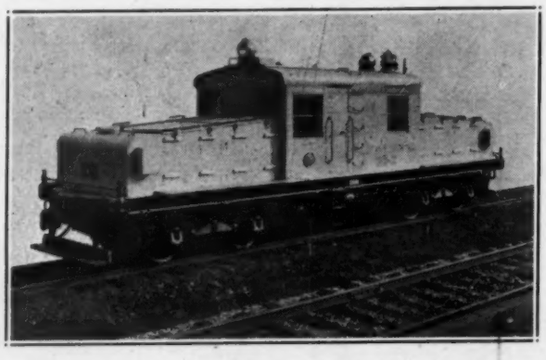


FIG. 5—60 ton double truck electric locomotive used for coal mining haulage by Foley Bros., Rosebud, Montana.

ovens would probably be equal to not more than 1500 feet on the general average. The locomotives can accomplish this cycle in a total scheduled time of about eight minutes.

One of the most important operations is the handling of hot metal from blast furnaces to Bessemer converters, mixers or open hearth furnaces. This hot metal from blast furnaces is handled in ladle cars. Service is continuous twenty-four hours per day and the tonnages handled are comparatively great. The use of electric locomotives for handling ladle cars involves special consideration of the method of supplying power to the locomotives. Tracks run into the buildings underneath furnaces, over numerous crossings, so that it is practically necessary to design some special form of collector trolley devices. Third rail shoes must be located far enough away from the main track to clear the casting bodies of the ladle cars. In spite of these handicaps numerous installations have been made. Some kind of self-contained locomotive is seemingly best adapted to the handling of hot metal ladle cars, except when it is possible to provide a means of contact which is not too elaborate and expensive. Continuity in service of this kind is absolutely essential.

The handling of materials for open hearth furnaces is another very important operation in the steel mill. It is desirable to use a storage battery for this work because the tracks are usually inside of the building for at least 800 or 900 ft. in front of the ovens.

The Erie Forge & Steel Company has in operation an 8-ton storage battery locomotive equipped with 50 kw-hr. battery, which has been in service since early in 1918. The battery was renewed in 1923 after five years service. Cars hauled by this locomotive are loaded by means of an overhead crane outside the building, the limestone, fluxing material, scrap, etc., being placed in the usual open hearth boxes. The material is hauled several hundred feet outside the building into the space in front of the ovens where it is placed in the furnace by means of an unloading machine. This locomotive operates continuously 24 hours per day, the battery being charged between trips.

Many open hearth furnace buildings are so located that the scrap material must be handled up relatively heavy grades and around sharp curves before trains can reach the furnace floor. In general 20 to 25-ton locomotives would be the most suitable units for this duty. Cars for open hearth work are usually very crude in design, and bearings are difficult to lubricate so that car friction is quite high. It is likely that a combination trolley or third rail and battery locomotive would be found most suitable from an electrical point of view for this class of work. With the battery unit it would be possible to enter the building on the charging floor without the use of trolley wires or third rails. It would also be possible to operate the locomotive at the scrap pile without the use of third rails.

There is an interesting application of electric locomotive at the Bethlehem Steel Company, Lackawanna Plant. This locomotive is extremely special, being built to handle ingot buggies. The locomotive is 12 tons weight, 36-in. gauge, is equipped with two 95-h.p. motors with fire proof insulation. The ingot buggy receives an ingot of eight to ten tons weight either from the hot metal car on one side of the track or from the soaking pits on the other side of the track, the ingot being placed on the car by an overhead crane. The locomotive then accelerates rapidly, pushing the ingot back up to the rolls. By means of a tilting device combined with the momentum of the trip the ingot is shoved directly into the rolls. This locomotive is capable of making 90 round trips per hour when handling ingots 300 ft. away from the rolls, making a total round trip of 600 ft.

One of the most important links in the chain of operations is the handling of ingot mould cars from the Bessemer Converter and open hearth furnaces to the stripping yards and thence to the soaking pits.

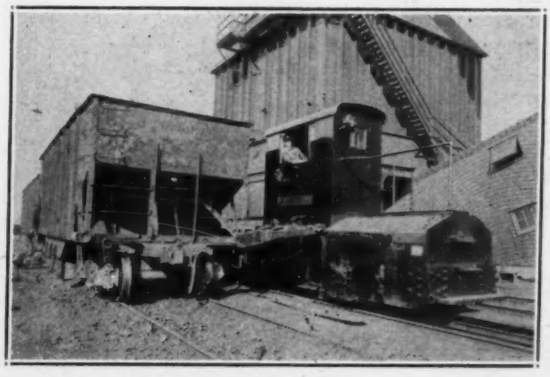


FIG. 6—25 ton side arm pusher locomotive operated by the Toledo Furnace Co., Toledo, O.

The common form of motive power is the small narrow gauge dinkey type locomotive. Tracks usually run in such places where clearances are small, curves and tracks are sharp and frequent. This service is continuous for 24 hours per day. Car frictions are very high, records showing sometimes as much as 100 lb. per ton. It is almost impossible to use trolley wires or third rails to handle this type of car. As to whether the cost of operating the battery locomotive

would be cheaper than steam depends upon the individual local conditions. There are very few, if any, electric locomotives installed for this work. This is a kind of service for which an oil electric locomotive might be suitable. Owing to the surrounding high temperature the use of gasoline fuel would be questionable.

As an example of the savings which may be expected by the use of electric locomotives, mention is made of a 5-ton storage battery locomotive, which

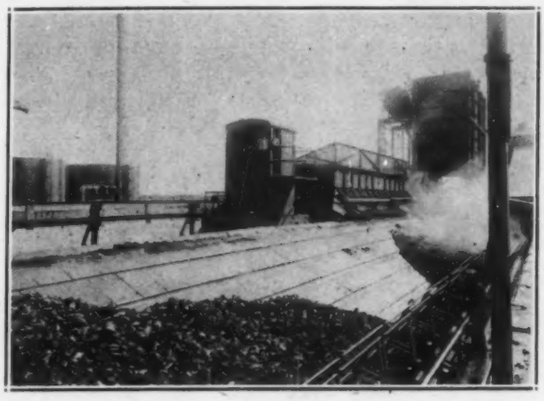


FIG. 7—Typical 20 ton coke oven locomotive handling coke quenching car.

was placed in service by the Youngstown Sheet & Tube Company. This locomotive had a drawbar pull of 2,400 lb. and a storage battery of 40 kw-hr. capacity. In using a dinkey locomotive for the particular service it gave trouble because of not operating smoothly. The battery locomotive proved entirely successful and incidentally reduced the cost of haulage by 46 per cent.

Electric locomotives have been found very serviceable on ore unloading docks. In order to spot the cars under the unloaders it was heretofore necessary to use a rope haul which usually operated at a speed of 90 ft. per minute. In conjunction with the rope haul a heavy steam locomotive was required to push a train of empty cars onto the dock, also a heavy steam locomotive was necessary to move the loaded train away from the dock.

The pusher type locomotive has been used quite frequently. There are a number of installations and the more recent one is at the Lehigh Valley Dock, Clairmont Terminal, New Jersey. This type of locomotive runs on a narrow gauge track between the standard gauge tracks and spots the cars by means of a pusher arm. The locomotives operate from double contact third rails, which are protected by a wooden planking. Locomotive places a string of empty cars on the dock at the required point of loading, spots them under the lower bridge hopper and finally pushes the string of loaded cars off the dock to the loading yard, which may be some considerable distance from the dock. The pusher arms may be raised and

FIG. 8—25 ton ladle hauling locomotive with double contact overhead conductor, 250 volts, operated by the Youngstown Sheet and Tube Company.

lowered so that the locomotive can run up and down the track and spot any car at the will of the operator.

Transportation of whatever kind and for whatever purpose so vitally concerns our welfare and prosperity that it is a privilege and an obligation to participate in the creation of better methods. It is much the same general problem whether it relates to the movement of people, merchandise or steel products.

Acknowledgment is given and thanks expressed to Mr. S. T. Dodd for his cordial co-operation and assistance in the preparation of this paper.

Economies of Steel Plant Railroad Electrification

By O. NEEDHAM AND DAVID C. HERSHBERGER*

THE tendency of the times at present is in the direction of more rigid economy in the manufacture and distribution of the products of the steel plants of this country. In the production of steel, transportation in and about the plant itself plays a very important part. The raw materials must be delivered to the blast furnaces, by-product plants and open hearth furnaces. Hot or cold metal is hauled from building to building, and the finished steel delivered to the connecting railroads. These operations represent a fair percentage of the operating expenses of a steel plant.

*General Engineering Department, Westinghouse Electric & Manufacturing Co.

The use of steam for driving the main rolls has proven to be wasteful, as compared with electric drive, even though the large, stationary engines received their steam from comparatively large boiler plants. As a result electricity has progressed to a point where it is almost universally considered for the driving of main rolls and auxiliaries, and the economies obtained very amply justify its application. Stationary engines used in driving rolling mills are rapidly being displaced by the more economical electric drive. In the last five years over one hundred main roll steam engines have been or are being replaced by electric motors after the owners have carefully investigated the economies to be effected thereby. It is estimated that in another decade the complete electrification of the more important main roll installations in this country will have been consummated. It is only natural, then, to inquire why, if electricity can so satisfactorily displace steam for driving mills, it cannot, with equal or greater economy, be used as a motive power on the plant railroad.

A large number of locomotives distributed around the yards with their small boilers, as compared with the stationary boiler, contribute to even more inefficient operation than the large, stationary engine.

Electric operation insures the economical conversion of the heat unit of the coal into useful energy at the locomotive. The coal is burned under conditions providing efficient evaporation of water into steam and in turn its efficient conversion into electrical energy in the large generating station for operating the steel plant.

Fig. 1 shows the 24-hour load on a typical steel mill generating station. There are several large main roll drives in this mill, and it will be noted that these diversify in such a way that the plant

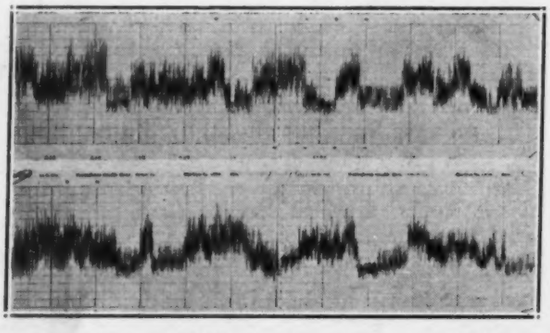


Fig. 1—Graphic Wattmeter Curve Showing Station Load on Generating Plant of a typical steel mill.

load is comparatively steady. The boilers and generating units are operating under very favorable conditions and can be operated at the point of best economy. If the yards are electrified they will draw their power from such a system and consequently, the plant will benefit by having its motive power produced in a highly efficient centralized plant rather than by a large number of isolated boilers and small steam units located on the locomotives.

The complete electrification of steel mill yards offers very attractive economies, and this statement is justified by results obtained in the cases where electric locomotives have been used in the mills for special purposes, such as handling of hot coke from ovens to the quenchers, ingots from soaking pits to the mills, hot metal from the blast furnace to the open hearth, etc.

The electrification of steam railroad terminals, mountain grades, tunnels and, in fact, whole engine divisions, has resulted in substantial savings.

Many of the older plants employ the narrow gauge railway system, as well as the standard gauge system. The problem is simplified if there is only a standard gauge system to consider, but since a large number of plants have both systems, it is necessary to treat them both in this paper in order to have a rounded-out view of the entire railroad electrification problem as related to steel mill yards.

For the purposes of this study, we have assumed a typical steel plant having both systems, i. e., narrow gauge, containing nine miles of track, and standard gauge, comprising 40 miles of track.

The Narrow Gauge Railroad System

The narrow gauge railroad system is distributed around the open-hearth furnaces and the mills in close proximity to the buildings, and is confined to a relatively small area and trackage.

This system employs small steam locomotives at present, and these in relatively large numbers considering the work to be done. This is due largely to the character of the manufacturing operations, which require locomotives distributed throughout the plant to take care of the work continuously in the production of steel by being available when needed.

They are frequently required to enter, and work inside the buildings and often cause considerable annoyance on account of the smoke and gases discharged in the buildings.

The Standard Gauge Railroad System

The standard gauge railroad system is also distributed throughout the plant, taking care of the transportation involving the use of standard railroad cars, ladle and slag cars, etc. The tracks comprising the standard gauge systems are mostly located on the outer sections of the mill area, with many branches running into the various mills and by the open-hearth buildings. The character of the work performed is diversified, but all of it comes under the class of switching service.

This system employs a moderate size locomotive designed for negotiating sharp curves. The number of locomotives required is also relatively large, due to the character of the work to be performed, which is distributed around the entire plant area.

TRACK

Narrow Gauge

The track gauges for the narrow gauge railroad systems of the country comprise such dimensions as 24 inches, 30 inches, 36 inches, etc. As near as can be determined at this time, the 36-inch gauge predominates. The rail weight varies from 75 to 85 pounds per yard, usually the latter value predominating for steel plant work.

Short curves are frequent on the narrow gauge railroad, which require locomotives of relatively short wheel base.

The grades around the steel plant frequently result from the difference in level between the open hearth pit and the charging floor. This difference in elevation results in grades, ranging anywhere from 2 to 4 per cent. They are usually of limited length, but have a definite influence on the weight of locomotive required to perform the service of serving the open-hearth furnaces. Other conditions enter in at the various plants to introduce severe grades, so that each application requires individual consideration.

Standard Gauge

Standard track gauge is 4 feet 8½ inches between rail heads, except on curves a slightly increased dimension is used for facilitating locomotive running. Rail weights usually in the neighborhood of 100 pounds per yard are used. Steel or wood ties are used for carrying the rails.

The curves are frequently very short in the track layouts around buildings and the grades are short, but may run as high as 3 or 4 per cent, particularly at loading pits.

STEAM MOTIVE POWER

Narrow Gauge

The present motive power on the narrow gauge systems comprises some very old equipment, some of moderate age and some relatively new. As a rule, this equipment is used in connection with the earlier mills. It is not possible, except at very great expense, to change over the present narrow gauge system to standard gauge, so that the former must be continued. The most recently constructed plants in new locations employ standard gauge locomotives for this work, and the mill tracks are laid out with adequate clearances.

The narrow gauge locomotives are of moderate weight, varying from 20 to 60 tons on the drivers. In some cases, small coal tenders are employed, while on others the coal box is a part of the locomotive. These engines are usually of the two-axle type, having 33 to 42-inch wheels and a total wheel base of from 5 feet to 7 feet. This type of construction requires relatively good rail conditions. The locomotives have simple engines and as a rule burn soft coal. They are not equipped with modern arch construction, superheaters, feed water heaters, etc., so that the relative consumption of coal is high and the locomotive as a whole is inefficient. It is realized that the addition of these refinements would make the locomotive more efficient, but would entail greater maintenance expense and add to the complication of operation, which on this size of locomotive, may not be justifiable for the economies to be obtained in fuel consumption. The table below gives a general idea of the narrow gauge motive power equipment for a typical plant. This is additional motive power apparatus to the standard gauge equipment listed later in this paper.

Number	Weight on Drivers Tons	Year Purchased
5	20	1907
3	35	1907
9	45	1912
4	60	1916
Total—21 Locomotives		

A total of 16 locomotives are required to perform the service and 5 extra locomotives are required as spares, some of which are regularly undergoing repairs, others are off duty for washing out, cleaning flues and fires, etc., while the remaining spares are held ready for service in emergency as required.

Standard Gauge

The steam locomotives employed on the standard gauge systems have had a wide range of time in service. Some have been in service from twenty to thirty years, while others are comparatively mod-

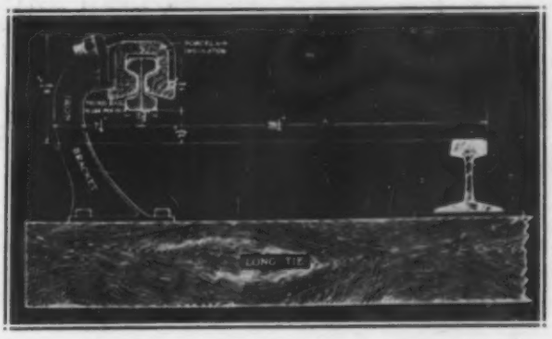


Fig. 2—Under Running Third Rail for 600 Volts D.C.

ern. The weight on drivers varies from 40 to 100 tons and upwards. Practically all locomotives in this service have trailing tenders for coal and water. These locomotives are usually of the three-axle type, with approximately 50-inch wheels, and wheel bases as high as 12 to 14 feet. These locomotives are no different from the narrow gauge locomotives as to steam consumption, as they also are not equipped with the fuel saving devices. The table given below will indicate the standard gauge motive power equipment required for a typical plant. This supplements the narrow gauge equipment listed above.

Number	Weight on Drivers Tons	Weight of Locomotive and Tender in Working order	Year Purchased
7	45	82	1907
5	65	107	1915
3	90	153	1919
Total—15 Locomotives			

A total of 15 locomotives are required to perform the service, three of them being extras for washout, repairs and standby service.

Operating Conditions—Narrow Gauge

The narrow gauge locomotives are used to serve the open-hearth furnaces and mills. They are employed to haul hot ingots in molds from the pouring floor to the strippers and ingots from the strippers to the soaking pits. They are also used in the scrap yard hauling scrap to the open hearth furnaces, etc. Part of this work is continuous, while some takes place at regular intervals and requires that locomotives be available without fail at these times.

It is of interest to note that the narrow gauge steam locomotives are operated by one man the same as the electric locomotives would be. A

second person or brakeman takes care of coupling and uncoupling the cars and as a rule does the firing of the locomotive. With electric locomotives this work would be made easier for the brakeman.

Observations were conducted at one plant to determine the service being performed, which might be used as a basis for determining the size of electric locomotives required, and to work up a comparison of performance and operating expenses. These data covering speeds, loads, length of run, etc., are shown in table Number 1.

TABLE NO. 1—SERVICE TEST ON OPEN HEARTH PIT LOCOMOTIVE

Taking Ingots from Open Hearth to Stripper 60-Ton Locomotive

Date of Test	3/24/26	Percent
Length of Test	3 hr. 52 min.	100
Time locomotive was in motion	1 hr. 32 min.	39.5
Time locomotive running light	0 hr. 27 min.	11.5
Time locomotive running loaded	1 hr. 5 min.	28.0
Time idle and lost in coupling	2 hr. 20 min.	60.5
Number of shifts light	37	
Number of shifts loaded	41	
Total number of shifts	78	
Average length of shift light—ft.	412	
Average length of shift loaded—ft.	712	
Average speed light M.P.H.	6.5	
Average speed loaded M.P.H.	5.1	
Maximum average speed light M.P.H.	13.1	
Max. average speed loaded M.P.H.	8.03	
Average weight of trailing load (tons)	241	
Average weight of loaded train (tons)	308.5	
Per cent locomotive weight to total train weight	21.8	
Maximum trailing load (tons)	300	
Total distance traveled (miles)	8.4	
Total distance light	2.88	
Percent total distance light	34.3	
Trailing ton miles, total	1330	
Tender ton miles	63	
Locomotive ton miles (tender included)	504	
Gross ton miles	1834	

Although this test only lasted for three hours and fifty-two minutes (3 hr. 52 min.), it should be kept in mind that it comprises several complete cycles of operation and therefore is in general, representative of a 24-hour operation. It can be taken to represent in general the heaviest service performed by narrow gauge locomotives. Some of this service took place on grades running as high as 2½ percent. It is interesting to note that the time the locomotive was running without load approximates 11.5 per cent of the total time, while the time running with load approximates 28 per cent of the total time and the time lost in coupling and standing idle is 60.5 per cent. This would indicate that the service on these locomotives is only moderately severe.

OPERATING CONDITIONS

Standard Gauge

The standard gauge locomotives are employed to haul hot metal from the cast houses to the mixers, haul away the slag from the cast houses and, in some operations, to handle ore, coke, coal and limestone around the furnaces and to haul away the finished products from the mills. A small percentage of this service consists of moving trains over the scales in the "weighing-in" and "weighing-out" service which entails a large number of accelerations of short duration. The general service conditions under which these locomotives operate are comparatively favorable.

The standard gauge locomotives are operated by regular crews consisting of engineer, fireman, brakeman and conductor, so that any reduction in locomotives means a considerable reduction in operating costs.

Table No. 2 gives data from tests taken to determine the character of the service performed by a locomotive on the standard gauge section of the yard.

TABLE II

SERVICE TESTS

STANDARD GAUGE LOCOMOTIVE

Service	Test No. 1 Billet hole			Test No. 2 Incoming and outgoing freight		
Weight on drivers	65			75 tons		
Total weight	107			115 tons		
Date of test	1926			1921		
	Hrs.	Min.	%	Hrs.	Min.	%
Length of test	3	32	100	7	16	100
Time locomotive was in motion	1	31	43	4	21	60
Time locomotive was running light		18	8.5			
Time locomotive running loaded	1	13	34.5			
Time idle and lost in coupling	2	1	57	2	55	40
Number of shifts light		18			15	
Number of shifts loaded		74			73	
Total number of shifts		92			88	
Average length of shift light (ft.)		518			1682	
Average length of shift loaded (ft.)		433				
Av. speed light (M.P.H.)		6.0			5.1	
Av. speed loaded (M.P.H.)		4.98				
Max. average speed light (M.P.H.)		9.35			10.6	
Max. average speed loaded (M.P.H.		8.25				
Average weight of trailing load (tons)		220			198.9	
Average weight of loaded train (tons)		327			313.9	
Per cent locomotive weight to train weight		32.7			36.7	
Maximum trailing load (tons)		858			1330.5	
Total distance traveled (miles)		7.95			26.57	
Total distance light (miles)		22.3			32.9	
Percent total distance light		1.78			8.75	
Trailing ton miles		1338			3530.4	
Tender ton miles		318			1010.3	
Locomotive ton miles (tender included)		550			3064	
Gross ton miles		1888			6596	
Gross ton miles per hour		534			905	
Pounds of coal per test					3960	
Pounds of coal per trailing ton mile					1.122	
Pounds of coal per gross ton mile					.615	

Test No. 1 in Table 2 indicates the service on a run known as the "Billet Hole" run. This locomotive performs the service of bringing in empty cars and placing them in the loading pit or billet-hole alongside the bar mill and removing loaded cars of steel bars from the billet-hole and weighing them out, then placing them in the outer yards for shipment.

Test No. 2 covers a three-day test, under the direction of Mr. R. B. Gerhardt, the data on which were presented in September, 1921, before this Association.

A comparison of the two tests would indicate that the service of the two are not greatly different on certain items for instance, the average weight of trailing load in tons is 220 for test No. 1 and 199 for test No. 2. The gross ton miles per hour for test No. 1 is 534, while for test No. 2 it is 905. This would indicate that test No. 2 comprised more severe service due largely to longer runs as the number of feet per run in test No. 2 was 1682, whereas in test No. 1 it was 518 for light engine and 433 feet for loaded run, so that the rate of work performed per hour would be greater in test No. 2 for this particular reason. The first test comprises a large number of short runs, while test No. 2 is composed of a smaller number of longer runs. These two tests tend to show that a large variety of services may exist in the various plants or even in any one plant from the standpoint of number of runs made and also tonnage hauled.

SYSTEM OF ELECTRIFICATION

This study is confined to the two most promising systems of electrification for steel mill yard work. These two systems are as follows:

1—The 250 volt direct current third rail system.

2—The Diesel-electric locomotive.

These systems are discussed under their respective headings following:

THE 250-VOLT DIRECT CURRENT THIRD RAIL SYSTEM

Power Supply

Practically all steel plants in this country use 250 volts for direct current auxiliaries and general mill use.

There is a distinct advantage in keeping all direct current consuming units, of moderate size, at the same voltage and allowing them to draw their power from a common source. The addition of yard locomotives to the existing mill system would provide a more diversified load and in all probability a better load factor. Since most existing mill systems are 250 volts, it will be the preferred voltage for yard electrification. The safety features resulting from the use of 250 volts rather than a higher voltage constitute an additional advantage for this voltage. Workmen coming in contact with conductors carrying 250 volts are less likely to be injured than when coming in contact with conductors carrying higher voltages.

It is almost imperative that for any major electrification a grounded system be used, otherwise the double third rail system will be required, and its cost and complications would be prohibitive except in very special cases. In some steel plants the mill circuit is solidly grounded at present, and for these the addition of third rail locomotives would present no new operating problems in this respect. In many other plants the D.C. system is in such condition that no difficulty would be encountered from grounding one side. Other plants may deem it objectionable to ground their D.C. systems and in such cases a separate system could be set up for operating the plant railroad. This would require a greater investment in additional converting apparatus than would be the case if the existing direct current system were grounded and the yard locomotives operated from the common network. Where the railway load would diversify with the mill load very little if any additional converting apparatus over that necessary for the mill load would be required.

This consideration would also enter largely into the selection of the voltage on which the yard locomotives would be operated. Most plants are now standardizing on a voltage of 230 to 250 volts for both alternating current and direct current auxiliaries and the same safety considerations, that dictate this voltage for mill auxiliaries, would influence the selection of the voltage for the yard locomotives. This would apply particularly to the narrow gauge systems which are found in most of the older plants.

Conducting System

The question of suitable conducting system has received considerable attention in previous papers read before this association. It is fairly well established that the overhead trolley, except in special applications, cannot be used in steel mill yards. One reason is that the yard locomotives should operate at 250 volts and the overhead trolley does not lend itself well to heavy operation at this voltage. The main reason, however, and the one which possibly decides the issue, is the conflict with the work of locomotive cranes. The locomotive crane is of such general usefulness in the steel plant yards that it is required to work at some time or other, on practically every section of the plant system. It would, therefore, appear that the third rail is the only practical type of conductor for use in this service. There are two types of third rails, namely, the "over-running" and the "under-running." Mr. R. B. Gerhardt, in a paper under the title of "Electrification of the Steel Plant Railroad," written for this Association in September, 1921, gave a very complete discussion on the subject of "Third-rail in the Yards." He discussed the subject from every angle and successfully established the feasibility of using third-rail in steel plant yards. The following items were covered:

1. Safety.
2. Blocking the free passage of switchmen or other employes through the yards.
3. Danger from material or hot metal spilling or falling on the rails.
4. Methods of crossing frogs and switches.
5. Methods of construction through the buildings or special places where conductor rail is objectionable.
6. Tie-up from wrecks.

These items cover the main questions that can be raised with regard to third-rail conductor, and it was shown that none of them present any insurmountable difficulties. They can all be met by entirely practical means.

It is necessary in every case to provide complete protection for the third rail. This protection has to be provided to prevent accidents to switchmen and other employes by coming in contact with the live rail and also must be rigid enough to provide

reasonable protection to the third rail by falling material or hot metal spilling on the rail. In the case of falling material a very substantial protection is required, and it is believed that the "under-running" type lends itself somewhat better to the kind of protection necessary than does the "over-running" type. In view of the feasibility of properly protecting the "under-running" type of third rail, it has certain advantages on installations of this type.

This type of third rail may be supported from cast brackets or from brackets made up of steel strap, preferably the latter in order to prevent breakage and furthermore, to utilize the product of the steel mill. This strap could be rolled on some of the mills in the plant and bent to shape at minimum expense.

The location of the third rail should, if possible, conform to the American Railway Association practices, as yards of this kind sometimes handle steam railroad equipment. Furthermore, the location of the third rail should be the same for either narrow gauge or standard gauge tracks for the reason that frequently the narrow gauge engines run over some of the same track as the stanadard gauge engines

Fig. 3—Locomotive with Steeple Type Cab and Double Trucks.

by the use of a third running rail or track rail. In this case it would be necessary to locate the third rail on the side of the track using the common rail for the two types of locomotives.

The third rail should be properly bonded and should be provided with sectionalizing switches to isolate defective sections and to avoid tieing up the entire yard on account of failure in any one part.

The track rails are normally used for the return circuit. Where a large number of tracks are parallel to each other, the conductivity of a properly bonded track system is very great. This provides ample carrying capacity to the substation, so that no trouble should result from electrolysis.

ELECTRIC MOTIVE POWER

Narrow Gauge

It is generally recognized that certain sections of a narrow gauge railroad system cannot be equipped with third rail. One of these locations is in the open hearth pit where it is difficult to maintain the present track rails on account of the great weight they are subjected to at times in the way of supporting the ladles and masses of steel resulting from clearing the ladles of "skulls" and sometimes of relatively large masses of steel resulting from defective pouring. Under these conditions the installation of a third rail, which is located higher than the running rails, is impractical. Another location is in the open hearth scrap yards, where steel is being transferred from standard gauge cars to narrow gauge cars. On the other hand, there are many sections of the narrow gauge system which may easily be equipped with third rail construction. It is evident then that combination locomotives are required for part of the work, while other sections of the system can be served with ordinary third-rail locomotives.

The combination locomotive should be a combination third-rail and storage battery type locomotive. It is preferable to make the transition from third-rail to self propulsion when going to sections of the track not having third rail, with minimum effort and manipulation of control. With a combination third-rail and storage battery type locomotive, the transition from third rail to the section not having third rail or vice versa is made with practically no effort on the part of the engine operator. It would seem that with all conditions considered the combination third-rail and battery type locomotive is the most applicable for this class of service and for this reason we have included the battery type of propulsion where there is no third rail.

It is estimated that the following narrow gauge electric locomotives would be required to replace the twenty-one narrow gauge steam engines listed above:

5—50 ton combination third-rail and battery type locomotives.
5—25 ton combination third-rail and battery type locomotives.
6—25 ton third-rail type locomotives without battery.

Total 16 locomotives.

Past experience in steam railroad electrification and in the electrification of steam railroad terminals justifies a material reduction in the number of locomotives. In one electrification the number of switching locomotives required in a classification yard was reduced from ten to seven in the substitution of electric for steam. On a certain main line railroad electrification the number of locomotives was reduced from thirty-three to twelve when changing over from steam to electric operation. In this study the number of locomotives in active service has been reduced from sixteen steam to fifteen electrics. One spare locomotive is provided. A greater reduction in number of locomotives in active service would be justified if it were clear that more of the operation could be pooled rather than require a large percentage of the locomotives to be assigned to a specific service at a specific track location.

The 50-ton combination third-rail-battery type locomotives would be of the double-truck type, having a total of four axles, each of which would be equipped with direct geared traction motor. A steeple type cab would be preferable, having the control equipment mounted in the central compartment and the batteries under the hoods. This locomotive is illustrated in general by Figure No. 3. The battery would be charged by floating on the third rail

and would always be available for instant service. The conditions of charging would be such as to smooth out the load peak on the direct current supply either at the generating station or at the substations, as the case may be. This type of locomotive is capable of negotiating sharp curves such as exist around steel mills on the narrow gauge system. The tracking qualities of such a locomotive would be much better than those of an equivalent weight or heavier locomotive of the same type having two driving axles. Experience has shown that an electric locomotive with a given weight on drivers can

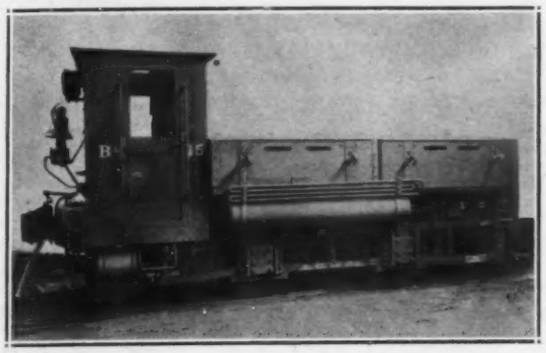


Fig. 4—Locomotive for Combination Third Rail and Battery Operation.

do more work than a steam locomotive having the same weight on drivers or conversely a given steam locomotive can be successfully replaced by an electric locomotive having a less weight on drivers. This is because the motors of an electric locomotive give a uniform tractive effort, whereas the cylinders of the steam locomotive provide a variable tractive effort. This uniform tractive effort minimizes the tendency to slip the wheels on the rails when accelerating heavy loads.

The 25-ton combination battery-third rail type of locomotive is shown in Fig. No. 4. This is a two-axle locomotive having an operator's compartment at one end and the battery carried over the main part of the locomotive. This engine would, as a rule, operate at relatively low speed and would have about the same tracking and riding qualities as the steam engine which it would displace.

The 25-ton third-rail type locomotive would be as shown in Fig. No. 4 except that it would not carry a battery, but would have the additional weight in the form of mechanical parts.

Standard Gauge

It is usually found that where the two gauges of track are employed, the standard gauge system can be equipped with third-rail throughout, so that all of the standard gauge electric locomotives would be equipped with third-rail shoes and would not carry batteries. This arrangement permits of very economical operation on the part of the electric motive power. In plants where the standard gauge system also is used to perform the work now being done by the narrow gauge system, a number of combination locomotives would be required as previously described under the narrow gauge system.

The following standard gauge electric locomotives are required to replace the 15 standard gauge steam locomotives listed above.

8—45 ton third rail type locomotives.
4—80 ton third rail type locomotives.

Total 12 locomotives.

A reduction of one locomotive in active service has been assumed, which in the light of past experience we believe, is fully justified. These locomotives will all be of the double truck type, each truck having two axles equipped with locomotive type motors direct geared to the axle. Swivel type trucks would be used to permit easy rounding of curves. The rigid wheel base would be much shorter than that of the steam locomotive, so that the electric locomotive has a pronounced advantage in negotiating short curves.

DIESEL ELECTRIC LOCOMOTIVES

The newest form of propulsion brought forth for transportation work is that of Diesel electric locomotives. These locomotives have characteristics which adapt them to certain classes of service, with the result that very marked economics can be realized over steam service. It is the general opinion at this time that the most promising field for the Diesel electric locomotive is in service where moderate size trains are to be hauled and where the length of track per locomotive is relatively large. Branch line railroad service is a promising field for this type of locomotive. It is also applicable to switching service in yards of extensive trackage requiring a small number of engines. Future developments may bring the Diesel electric locomotive to a point where it would be used extensively in main line work for the propulsion of heavy trains.

Diesel electric cars are now in operation with good results on the largest railroad system in Canada.

In view of the interest in the development of the Diesel electric locomotive, investment and operating costs are included in this study, in an endeavor to place before the industry the status of this type of motive power. Due to the relatively short pe-

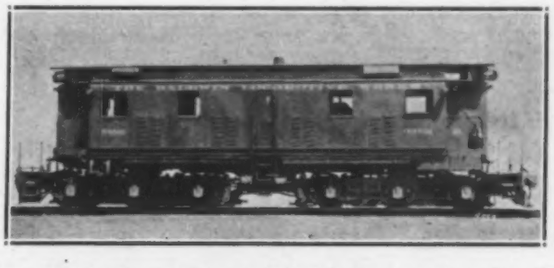


Fig. 5—1000 H. P. Diesel Electric locomotive for Main Line and branch line service.

riod of time that Diesel electric locomotives have been in service, complete data on operating and maintenance costs over long periods are not available.

Fig. 5 illustrates a 1000 H.P. Diesel electric locomotive for main and branch line service.

Upon first thought it would appear that the Diesel electric locomotives should make a very favorable showing in steel mill yard service. So far as its performance is concerned, the locomotive is well adapted for this service, but on account of the relatively high investment costs there is not as prom-

ising an outlook for the Diesel electric as for the third-rail type of locomotive, as will later be shown in this paper.

This type of locomotive may be put in service where the steam locomotives are now operating, without the necessity of erecting a third rail, and furthermore, may be placed in service a few at a time.

Narrow Gauge

The Diesel electric locomotive would be capable of performing the service on the narrow gauge railroad very satisfactorily in the open hearth buildings, both on the pouring floor side and on the charging side of the furnaces. The operation in the scrap yard would be handled better with Diesel electric locomotives than with third rail type locomotives.

It is estimated that the following Diesel electric locomotives would be required to replace the twenty-one steam engines previously listed under steam motive power—narrow gauge.

12—25 ton Diesel electric locomotives.
5—50 ton Diesel electric locomotives.

Total 17 locomotives.

It will be noted that one more Diesel locomotive is assigned to this service than with the third rail battery type, for the reason that engine trouble in connection with the Diesel engine would probably take the engine out of service for several days, leaving no spares available in case trouble developed on the engines in active service. For this reason two spare locomotives have been included. This number of locomotives is also based on the assumption that the Diesel electric locomotive can do as much work in a day as the third-rail type locomotive, which assumption may be permissible in view of the fact that the third-rail type locomotive is not busy at all times. In severe switching work, where the locomotive would be required to be in motion a greater percentage of the time than in this work, it is possible that additional Diesel engines would be required. On the other hand, it may be argued that a greater reduction, as compared with steam, would be permissible, which would apply both to the third-rail type and the Diesel electric type.

Standard Gauge

The field of application for the Diesel electric locomotive is, from the viewpoint of economies, more favorable on the standard gauge lines than on the narrow gauge lines for the reason that a greater amount of trackage must be equipped with third rail for the electric locomotive.

In plants where standard gauge is used throughout, the Diesel electric would be equally applicable to the combined services now performed by narrow gauge and standard gauge track in certain plants. The total number of locomotives could undoubtedly be considerably decreased over that required with the two systems of gauges.

The following Diesel electric locomotives are estimated as being required to replace the 15 standard gauge steam locomotives previously listed:

9—50 ton Diesel electric locomotives.
4—80 ton Diesel electric locomotives.

Total 13 Diesel electric locomotives.

It is assumed that the active service can be performed with one locomotive less than with steam, so that the total number of locomotives in active service would remain at 11, the same as for the all-electric system. The two spare locomotives would provide against conditions requiring a spare locomotive when one of the engines was in the shop undergoing repairs.

INVESTMENT COSTS

Narrow Gauge

The investment costs of the equipment for the 250-volt third-rail electrification and that for the Diesel electric locomotive, given in Table III, are based on present-day prices. The cost given for the steam locomotives is the total of the original purchase prices of the locomotives in the years indicated.

The item of generating and converting equipment has been taken care of in the price of power delivered to the direct current bus. Many of the plants would be in position to supply power to the third-rail system at many points without changing their present arrangement of sub-stations, whereas other plants may find it necessary to install sub-stations at one or more additional points.

The values used for third-rail construction are representative of average costs based on using 50-pound rails for the conductor rail. Seventy per cent of the nine miles of track would be equipped with third rail, making 6.3 miles of third-rail construction.

TABLE III

INVESTMENT COSTS
NARROW GAUGE SYSTEM

Equipment	250 Volt Third Rail System	Diesel Electric	Steam
Five—50-ton combination third-rail and battery-type locomotives			
Five—25-ton combination third-rail and battery-type locomotives	$380,000		
Six—25-ton third-rail type locomotives			
Twelve—25-ton Diesel electric locomotives		$827,000	
Five—50-ton Diesel electric locomotives			
Five—20-ton steam locomotives, 1907			
Three—35-ton steam locomotives, 1907			$179,000
Nine—45-ton steam locomotives, 1912			
Four—60-ton steam locomotives, 1916			
6.3 miles of third rail and bonding	61,700		
Total	$441,700	$827,000	$179,000
Scrap value of old locomotives	12,000	12,000	
Net investment	$429,700	$815,000	

Standard Gauge

The investment costs given in Table IV cover the equipment required for the electric locomotives and 250-volt third-rail system, the Diesel electric

locomotives and steam locomotives. The costs for the first two items are taken at present-day prices, while steam locomotives are charged in at their original purchase prices in the years indicated in the table.

Equipment for converting from AC to 250 volts DC in connection with the 250-volt third-rail system has been taken care of in the same manner as for the narrow gauge system previously discussed.

TABLE IV

INVESTMENT COSTS
STANDARD GAUGE SYSTEM

Equipment	250 Volts Third Rail System	Diesel Electric Locomotives	Steam
Four—80-ton third rail locomotives	$496,000		
Eight—45-ton third rail locomotives			
Four—80-ton Diesel electric locomotives		$1,025,000	
Nine—45-ton Diesel electric locomotives			
Seven—45-ton steam locomotives, 1907			
Five—65-ton steam locomotives, 1915			$203,000
Three—90-ton steam locomotives, 1919			
40 miles of third rail and bonding	392,000		
Total	$888,000	$1,025,000	$203,000
Scrap value of old locomotives	19,000	19,000	
Net investment	869,000	1,006,000	

OPERATING COSTS

Narrow Gauge

The total yearly operating costs for electric operation, Diesel electric operation and for steam operation, are shown in Table V below:

Note—This comparison is made on the basis that the steam locomotives are evaluated only at scrap value, and that no interest or depreciation is charged against them.

TABLE V

NARROW GAUGE RAILROAD
OPERATING COSTS PER YEAR

	Electric	Diesel Electric	Steam
	5-50 ton—third rail and battery		5-20 ton
			3-35 ton
	5-25 ton—third rail and battery	5-50 ton	9-45 ton
		12-25 ton	4-60 ton
	6-25 ton—third rail		
	16—Total	17—Total	21—Total
Maintenance of locomotives, including engine house expense (exclusive of batteries on electric locotives	$ 6,860	$ 24,550	$ 80,000
Battery renewals and maintenance	17,200		
Supplies and lubricants	275	7,900	2,700
Crew expense	137,600	137,600	146,800
Electric energy	22,000		
Diesel oil		19,200	
Coal			74,400
Water			1,600
Ashes			1,500
Maintenance of third rail	945		
Operating cost	184,880	189,250	307,000
Interest depreciation, taxes, insurance	59,500	124,000	3,600
Total annual charge	$244,380	$313,250	$310,600
Yearly saving over steam	66,220	(—) 2,650	
% return on net investment shown in Table III	15.5%	—%	

The maintenance of the 250-volt, combination third-rail and battery-type locomotive was segregated to show the maintenance of the locomotive proper, and its battery separately, in order to obtain a better idea of the relation of these two items. A locomotive without battery would have the same maintenance as shown under the first item.

The small reduction in crew expense by electric operation over steam is the result of the elimination of only one locomotive from active service. Further investigation may reveal that the number of locomotives required in actual operation could be reduced more than one, this resulting in increased economics.

The electric energy cost was figured at 1.2 cents per kilowatt-hour at the direct current bus. This value will ordinarily cover the expense of supplying direct current at this point, including generation, conversion and distribution.

The cost of coal was taken at $3.75 per ton delivered on the tender of the locomotive. In general, this price would apply to the Pittsburgh district, where coal is available at relatively low prices. In a number of other districts this cost may go as high as $6.00 per ton, which would increase very materially the cost of operation of steam locomotives and would increase to some extent the cost of electric power.

Third rail maintenance on many railroads is almost negligible. In steel mill service, however, it may be expected that this item would be somewhat higher than that of main road electrification, or railroad terminal electrification. The total trackage on the narrow gauge system would be approximately nine miles and seventy per cent of it would be equipped with third rail, making 6.3 miles of third rail installation. The maintenance of the third rail was taken at $150 per mile, but subsequent information would indicate that for steel mill work this value may be reduced somewhat.

The item of interest, depreciation, taxes and insurance will bear further amplifying, especially in view of the many opinions held regarding depreciation. The fixed charges in the following table would appear to be adequate.

	Steam	Electric
Interest on investment	7%	7%
Insurance and taxes	2%	2%
Yearly amount set aside for sinking fund	3%	1½%
Total	12%	10½%

The sinking fund set aside is that required to equal the original cost of the locomotives either steam or electric when put at interest at 5% annually. The life of the steam locomotive is assumed to be twenty years, and the comparative life of an

electric locomotive is assumed to be thirty years. It is a known fact that both types of equipment have been in service for these respective periods. However, to conform to steel mill custom of the past the fixed charges have been taken at 15% for the steam and for Diesel electric, while for the 250-volt D.C. equipment it has been taken at 13½% on account of its lower depreciation due to longer, useful life.

Particular attention is directed to the item of interest, depreciation, taxes and insurance for the steam locomotive of $3,600. This value is arrived at on the assumption that it is decided to electrify, and that the steam engines would be charged only insurance and taxes at 2% on the original cost.

This represents the worst possible condition. It assumes that only scrap value can be received for all the steam locomotives. Many of the locomotives may be comparatively new and in good condition, in which case it is entirely probable that a fair price can be obtained for them. Any funds thus realized would logically be applied on the purchase of the electric locomotives. This would reduce the net investment in electric locomotive and increase the per cent return on the investment over that shown in the table.

The depreciation included in the fixed charges under operating expense is set aside as a sinking fund for the retirement of the old locomotives. Under regular accounting methods this sinking fund would bear interest and be available for the purchase of new motive power and hence an accumulated sinking fund of $110,400 should be deducted from the net investments shown in Table III to arrive at a true net investment for new equipment. This would reduce the net investment for the 250-volt third rail system to $319,300 and the return on the net investment with a saving of $66,220 per year over steam operation would be $20.7%.

The operating costs given for narrow gauge Diesel electric locomotives are the best estimates which we can make at this time in view of the limited service to which Diesel electric locomotives have been performing to date. On account of the high fixed charges resulting from the high first cost of this type of locomotive and the low fixed charges taken for the steam locomotives, a loss is shown for Diesel electric. The fixed charges were taken at the same percentage as for steam locomotives for the reason that at this stage of the art it is not known whether the locomotive would have a life of more than twenty years, which is the same as was taken for the steam locomotive.

Standard Gauge:

The operating costs on yearly basis for all-electric operation, Diesel electric operation and steam operation are shown in Table VI.

(Note—This comparison is made on the basis that the steam locomotives are evaluated only at scrap value and that no interest or depreciation is charged against them.)

The operating costs for the standard gauge locomotives are typical and have been worked up on much the same basis as those for the narrow gauge locomotives previously discussed. The item of "Crew Expense" shows a very great reduction over steam due to the fact that only one man is required per locomotive and also that with a reduction of one locomotive in active service, three crews are eliminated, one on each of the three eight-hour shifts. This results in a very pronounced saving in this item.

TABLE VI

STANDARD GAUGE RAILROAD OPERATING COSTS PER YEAR

	Third Rail Electric	Diesel Electric	Steam
	8—45 ton 4—80 ton	9—50 ton 4—80 ton	7—45 ton 5—65 ton 3—90 ton
	12—Total	13—Total	15—Total
Maintenance of loco's. including engine house expenses	11,100	42,900	101,000
Supplies and lubricants	475	7,000	3,500
Crew expenses	181,800	181,800	254,000
Electric energy	19,000		
Diesel oil		16,500	
Coal			117,500
Water			2,000
Ashes			1,900
Maintenance of third rail	6,000		
Operating cost	218,275	248,200	479,900
Interest, depreciation, taxes and insurance	119,800	153,750	4,050
Total annual charges	338,075	401,950	483,950
Yearly saving over steam	145,875	82,000	
% Return on net investment shown in Table V	16.8%	8.2%	

The same number of Diesel electric locomotives is assumed to perform the service as with the straight electric locomotives, this also being based largely on the fact that the engines are not in motion all the time and that the Diesel electric locomotive would be sufficiently speedy to perform the service.

The return on the net investment is 8.2% after providing for fixed charges. This percentage is much more favorable than for the narrow gauge system due to the fact that there are fewer locomotives per mile of track with a consequent relative reduction in capital expenditures and fixed charges.

Narrow and Standard Gauge Systems Combined

In order to obtain a composite view of the electrification of the narrow gauge and the standard gauge systems combined, Table VII is submitted.

TABLE VII

STANDARD AND NARROW GAUGE SYSTEMS COMBINED

Comparative operating and investment costs displacing present steam locomotives by third rail or Diesel electric locomotives.

Note: This comparison is made on the basis that the steam locomotives are evaluated only at scrap value and that no interest or depreciation is charged against them.

	Third rail Locomotive	Diesel elec. Locomotive	Present Steam Locomotives
Operating cost	403,155	437,450	786,900
Fxed charges	179,500	277,800	7,650
Total annual charge	582,655	715,250	794,550
Yearly saving over steam	211,895	79,300	
Net investment	1,298,700	1,821,000	382,000
Per cent return on net investment	16.3	4.35	

The return on the investment shown in Table VII is the minimum to be expected. There are three items which may operate to increase the return on the investment. These are (a) scrap value; (b) fixed charges on steam locomotives, and (c) accumulated sinking fund.

The scrap values are the absolute minimum which may be realized in disposing of the old locomotives. If they are sold at their full value, the salvage value will be greatly increased and the net investment reduced below the values used in the table.

The fixed charges on the steam locomotives have been suppressed to an absolute minimum. These are susceptible to revision upwards, depending upon the viewpoint taken.

The accumulated sinking fund may be taken as a credit. In the case under consideration this fund would amount to $205,400, thereby reducing the net investments by this amount.

Taking advantage of these items would raise the return on the net investment to over 25% for the third rail type locomotive and to over 15% for the Diesel electric locomotives.

TRANSPORTATION SYSTEMS FOR NEW STEEL PLANTS

A comparative study of transportation systems for new steel plants places electric operation in even better position than where steam locomotives are now in operation. This is brought about by the fact that new steam locomotives are more expensive and carry a higher total fixed charge than for old engines. The result is that the return on the investment is very satisfactory and fully justifies electric operation as compared with steam.

TABLE VIII

NARROW GAUGE RAILROAD

Comparative Operating and Investment Costs for Third Rail Type, Diesel-Electric and New Steam Locomotives

	Third Rail Locomotives	Diesel Elec. Locomotives	New Steam Locomotives
Operating Cost	$184,880	$189,250	$307,000
Fixed Charges	59,500	124,000	60,500
Total Annual Charge	244,380	313,250	367,500
Yearly Saving Over Steam	123,120	54,250	
Investment	441,700	827,000	402,600
Per Cent On Investment	27.9	6.55	

The per cent saving over steam is much more favorable than in the case where old engines are displaced by electrics, as shown in Table V.

The 250-volt third-rail locomotives and third rail costs $39,100 more than steam and the saving is $123,000 per year, so that the return on the additional money invested for electrification is three times the additional investment.

TABLE IX

STANDARD GAUGE RAILROAD

Comparative Operating and Investment Costs for Third Rail Type, Diesel Electric and New Steam Locomotives

	Third Rail Locomotives	Diesel Electric Locomotives	New Steam Locomotives
Operating Cost	$218,275	$248,200	$479,900
Fixed Charges	120,000	153,800	56,300
Total Annual Charge	338,275	402,000	536,200
Yearly Saving Over Steam	197,925	134,200	
Investment	888,000	1,025,000	375,000
Per Cent Saving on Investment	22.3	13.1	

The 250-volt D.C. system will cost $513,000 more than new steam locomotives. With a saving of $198,000 in operating expenses the return on the additional investment is 38%

TABLE X

STANDARD AND NARROW GAUGE SYSTEMS COMBINED

Comparative Operating and Investment Costs for Third Rail Type, Diesel Electric and New Steam Locomotives

	Third Rail Locomotives	Diesel Electric Locomotives	New Steam Locomotives
Opearting Cost	$403,155	$437,450	$786,900
Fixed Charges	179,500	277,800	116,800
Total Annual Charge	582,655	715,250	903,700
Yearly Saving Over Steam	321,045	188,450	
Investment	1,329,700	1,852,000	777,600
Per Cent Saving on Investment	24.2	10.1	

The investment cost given for steam locomotives does not include:

1. Cost of coaling stations.
2. Cost of water lines, tanks, pumps and watering stations.
3. Ash handling facilities.
4. Additional repair shop facilities over that required for electric locomotives.

These facilities, together with their fixed charges and upkeep not being included, does not prevent the earning of an excellent return (after deducting fixed charges) on the investment required to pay for electrification.

The additional capital required to put both narrow and standard gauge systems in 250-volt electric operation instead of steam is $552,100, and the yearly saving is $321,045, or a return of 58% on the additional capital required.

General

The tables included in this paper show the worst conditions and give the minimum return that can be expected from electrification. There are a number of possibilities that could be taken into account that would improve the savings shown by either the 250-volt third-rail locomotive or Diesel Electric.

Only scrap value has been used on the present steam units; also no advantage has been taken of any possible sinking fund that may exist. If the engines could be disposed of at more than scrap value and if a sinking fund is available, both of these items could be applied on the purchase of the electric locomotives. This would decrease the amount of new capital which would be put in and increase the per cent return on the net investment.

No charge has been made for the upkeep of water and fuel stations required for the transportation system, nor for fixed charges on these items.

No consideration has been given in this paper to the electrification of the locomotive cranes, but the economies resulting from this step in conjunc-

tion with the use of the 250-volt third-rail system would be very appreciable as pointed out in a previous paper delivered by Mr. R. B. Gerhardt in September, 1921, before this Association. In this paper, Mr. Gerhardt states that the approximate saving for ten cranes in operation would amount to $70,000 annually, were they electrified, and operated from the third rail system .

In view of the great serviceability of the electric locomotive we believe there is a possibility of a further reduction in number of engines which would result in a greater reduction of operating expense and fixed charges.

While it has been mentioned that higher coal costs exist in certain locations, no advantage has been taken of this feature.

The working conditions in the steel plants would be very materially improved by the elimination of steam locomotives. The gases and smoke from the blast furnaces and open hearth furnaces are carried high in the air by tall chimneys and stacks, whereas the switcher locomotive pours forth dense smoke which floats throughout the mills and not only impairs the working conditions, but jeopardizes, to a certain extent, the safety of the employes. Furthermore, the blast from the exhaust has a deteriorating effect on all buildings and structures. This is an unevaluated item that might properly be included in this study.

It is believed that the showing made by the Diesel Electric locomotive in this comparison is not the last word on this excellent unit. It is entirely applicable to this class of service. Its cost of operation is rather high and the figures used are believed to be as accurate as can be estimated at the present time. This unit has sufficient merit to warrant its consideration and use in this service. The unevaluated advantages mentioned above apply as well to the Diesel Electric as to the third-rail electric and many installations of Diesel Electric locomotives will no doubt be made in the near future. It would be interesting to have another paper on this subject after a more extended experience has been had with the operation and maintenance of the Diesel Electric locomotive.

Conclusion

The 250-volt direct current system, employing third rail type locomotives, is the most economical system of transportation for steel plant yards. The return on the investment as compared with steam operation, is excellent and fully justifies the displacement of steam by electric motive power. A number of partial installations of this type are in operation with excellent results.

The Diesel electric locomotive occupies second place in point of operating economy and return on investment as compared with third rail locomotives. The future of this type of locomotive is very promising and an extensive application of this type of motive power is anticipated.

New steel plants should employ electric motive power from the beginning rather than start with steam with the idea of changing over to electric later. The difference in investment costs are so quickly eliminated by the economies of electric operation as to leave no doubt as to the course to be pursued.

The steel plants cannot afford to continue to purchase new steam locomotives to replace worn-out units. The changeover to electric operation can be made in sections and a progressive program of electrification put through without heavy expenditures at any one time.

The working conditions would be improved by the elimination of smoke, dirt and noise from the operation of steam engines.

The electric locomotive receiving its power from a conductor, is the most reliable unit of motive power in existence. This has been fairly demonstrated in a large number of electrifications, some of which have been operating from twenty to thirty years. The third rail type locomotive has desirable features of operation that it will be difficult for other types to equal. It is quickly made ready for service, and its power is not limited by any local power plant on the locomotive itself for the reason that it has the steel plant power system behind it. It can handle heavy loads at moderate speeds, and its general performance recommends it over other types of locomotives when a suitable conductor system can be installed.

Finally, it may be accepted without doubt that the complete electrification of steel plant yards would result not only in very large economies of a direct nature, but of indirect benefits which cannot be evaluated.

How Electric Industrial Truck and Tractor Equipment is Effecting Savings in the Iron and Steel Industry

By HAROLD J. PAYNE*

THE importance of transportation within iron and steel plants is too well understood by you to require the presentation of supporting evidence. Further it is generally accepted that in maintaining a smooth flow of material through the plant, results rather than methods and equipment demand primary consideration. In a business where first things must be put first this is logical—and it is certain that the first essential in this industry is production.

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The primary business of the engineer is to save money for the owners of the enterprise with which he is associated and it is because failure to maintain production is so costly that his first responsibility is to keep wheels turning on schedule. In merely doing this however the engineer is not completely fulfilling his responsibility. Beyond getting a job done there is the requirement that the best possible means for accomplishing that job be discovered and applied. In transportation the application of this principle demands that although it is definitely known, for instance, that wheelbarrow pushers can keep a job moving, continuance of this method cannot be justified if power equipment for accomplishing the same work can be installed and operated at a fraction of the cost involved in the manual operation.

Consider the importance of the fact that in this industry five laborers could be employed 12 years ago for what two cost today. In other words the cost of the manual job now performed as it was in 1914 is two and a half times greater. Competition enters to make the argument for the use of modern handling equipment more effective—because, for practical purposes, it is largely production cost that determines selling cost, and selling cost determines the effectiveness with which competition can be met.

If we analyze the possibilities for continuing to cut production costs in various branches of this industry, we find that it is very often in improvement of transportation methods that most promising possibilities exist for savings. This may be partially accounted for on the basis of two facts (1) that in the past gaps not capable of being filled by heavy, high capacity equipment have not received their fair proportion of attention and (2) that up to the time when the cost of labor began to soar, boards of directors were inclined to favor appropriations for major changes in process equipment rather than relatively insignificant budgets for patching up the leaks in faulty transportation operations when recommendations were made in this connection.

Equipment That Fits Wins

It is an axiom, however, that over a period of years the equipment that fits a job to best advantage must come into use Progressive plants in every industry constantly plough profits into equipment for this reason. Andrew Carnegie attributed much of his success to his custom of replacing any machine, any method, or any plant as soon as something better presented itself. He is known to have scrapped millions of dollars worth of new machinery because he had secured other equipment, probably at greater expense, which he knew would reduce the unit cost of production and in time earn a larger return, even with the additional investment included.

Returning to the business of transportation, from which further digressions will not be made, it is significant that the application of this principle introduces the necessity for applyiug certain types of equipment that are designed to aid labor now working manually.

The electrical industrial truck and the tractor that are to be discussed here, represent one of many types of equipment for meeting materials handling problems effectively. Because of its fiexibility, adaptability and comparatively low cost, however, the electric industrial has a breadth of application in the industry that is unusual.

There are five major modifications of the electric industrial truck—and in addition there are several special trucks made to meet the demands for unusual service.

The first storage battery propelled truck for industrial service was of the straight platform type. Loads have to be handled on and off by hand, or by auxiliary equipment such as bracket cranes placed at strategic points.

This unit, because of its usefulness in towing trailers, led naturally to the development of the non-load carrying tractor—a trackless locomotive.

Another refinement of the straight platform type is that in which part of the load-carrying space is used for mounting a crane.

The advent of the elevating platform and of the tiering trucks marked a great advance because of

FIG. 1—Handling Crank Shafts in 3-Ton Loads With Elevating Platform Truck

the decrease in handling made possible by the use of skid platforms. No appreciable time is required for these machines to pick up or drop their loads. The tiering truck, carrying its load to heights of 10 feet, provides means for combined horizontal and vertical handling within wide limits.

In addition to these standard trucks—the low lift elevating platform is now built in capacities up to 10 tons—there is among others, a ram modification for rod handling, a fork lift for tin plate, a pot charger for use in annealing furnaces and a box charger for heat treating or carbonizing furnaces.

With such a range of equipment, there is sometimes a difficult problem in selection of that type and capacity which best fills the demands to be met. Little can be said in the way of generalization, except, perhaps, on the question of capacity. Usually it pays to install a machine larger than that figured as being absolutely needed and to provide battery capacity sufficient to operate the truck for a period of 8 hours. In this connection the services of engi-

neers who have specialized in the application of this equipment are invaluable.

Trucks for Charging Blast Furnaces

The quantity of material handled at a modern blast furnace is very large. A furnace turning out 400 tons will have to be fed every twenty-four hours with approximately 800 tons of ore, 400 tons of coke and 200 tons of limestone, or a total of 1400 tons of solid materials. From these figures, it is clear that large quantities of bulk material have to be handled, necessitating either a large labor force or mechanical-handling equipment.

From the material handling standpoint there are three types of furnaces: (a) hand-filled elevator furnaces, (b) skip-filled furnaces without larry car equipment and (c) skip-filled furnaces with larry car equipment. At the first two types of furnaces industrial trucks may be used to advantage in speeding up the charging, reducing the labor expense and relieving a shortage in a very specialized type of labor.

In the earlier types of elevator furnaces, the charges are handled in two-wheel buggies. These

FIG. 2—The Detroit Steel Products Co. Moving Skid Loads of Springs.

buggies are pushed from the storage bins to the elevator at the furnace and then lifted to the charging stage, where two men empty them into the charging bell. One of these buggies loaded with ore weighs from 1400 to 1600 pounds, and the man who pushes this load comes under the heading of selective labor. He is especially trained for this very heavy work and his muscles have become hardened to it. This class of labor is very scarce and it is very difficult to break in new men.

All of the more modern furnaces are mechanically charged. They are equipped with a skip hoist which receives its load from a hopper at the ground level and discharges into the charging bell on top of the furnace. The materials are conveyed from the bins to the hopper by means of the same buggies used with the hand-filled furnaces.

The latest types of furnacesare equipped with electric larry cars, which replace the buggies and laborers for handling the charge. On this type of furnace there is no application for industrial trucks.

Among others, five furnaces of the Carnegie Steel Company have been equipped with trucks and a brief description of the work being done will supply useful data for working out similar problems. Those furnaces equipped include two at Bellaire, O., Lucy furnace at Pittsburgh, and two furnaces at New Castle, Pa.

At the time when it was equipped furnace No. 2, at Bellaire, was of the hand-filled type first mentioned. Between the wheels of each of the old buggies, a sub-frame made of angle iron was built. This frame was placed about 12 inches from the ground, allowing sufficient clearance for handling with a standard elevating platform truck. The buggies were picked up at the elevator, carried to the ore pocket and returned to the elevator.

It is my understanding that at present this scheme has been modified and that four standard dump trucks are in use.

When hand buggies were carried by the elevating platform trucks, however, a total of six trucks with 13 operators is said to have replaced 54 specialized laborers.

Furnace No. 1 at Bellaire is of a more modern type and is equipped with a skip hoist for mechanical charging. It is a large furnace and is turning about 510 tons of pig per day. There are 39 charges per day split up into 78 sections, each consisting of 26,000 pounds of ore, 6,500 pounds of stone and 13,000 pounds of coke. The ore and stone is being handled by three trucks with end dump bodies, which have replaied 7 men and buggies. Two trucks are used for handling coke. This makes 5 trucks in all to handle the charging. These trucks require 15 drivers for the 3 shifts who can be recruited from almost any class of labor as against 45 specialized laborers who are very difficult to obtain.

Clinton Furnace at Pittsburgh uses 32 cubic feet capacity side dump bodies on straight platform trucks for charging. When 600 tons of ore are being charged per day a single truck does all of the handling. The average distance from bins to hopper, where the loads are dumped into the double skip hoist, is approximately 75 feet. In the runway from bins to skip there is a clearance of only 52 inches, but no difficulty has been experienced in operating under this conditoin. Aside from tires, that are replaced once in 8 months, and regular lubrication, no maintenance expense has been required.

It is known that a single truck makes a saving of 4 men per turn. Although 3 trucks were purchased for this job it is only rarely that more than one is used at a time. The entire investment made, however, amounting to about $10,000, was written off after 4 months of operation. In addition to direct savings, it has been found that this method of handling ore has made it possible to get rounds in regularly, thus increasing the uniformity of operation and of product. Moreover, labor turnover has been diminished.

The battery with which each truck is equipped is sufficient to operate the truck for one eight-hour shift and one extra battery is therefore necessary for each truck in regular operation. The cost of operating such an installation, exclusive of the drivers, but including depreciation, interest on the investment, maintenance, and charging current is approximately 50 cents per truck per hour. In view of the fact that this is a 24-hour a day operation, and in order not to run the risk of any breakdown, it is

usually considered good practice to purchase one spare truck for every three or four trucks.

Bodies for this class of work should be fabricated from ¼-inch plate and must be well made throughout.

Most installations are already equipped with floor scales for weighing the charges. The trucks may, in some cases, necessitate larger floor scales or the furnace superintendent may prefer to have a scale built right into the truck. In the past it has been found impossible to construct a scale unit that would function satisfactorily when made a permanent part of a truck, but at least two trucks thus equipped are performing to excellent advantage at the present time, in a foundry where the work done consists of charging cupalos.

Open Hearth Work

The transportation needs of the open hearth department are such that it has seemed unwise to recommend the industrial electric, except for special jobs. Electric cranes, charging machines and the plant railroad system have provided adequate facilities for keeping down lost motion in the performance of most essential operations.

For handling ashes from producer plants and from coal-fired boiler plants, several installations of the industrial electric have been made. At the Briar Hill plant of the Youngstown Sheet and Tube Company, two 2-ton trucks with 24 V dump skid bodies have been used for this work since 1920. This equipment is in operation 24 hours a day and so, by the usual criterion, the trucks have successfully completed 18 years of service.

The rebuilding of open hearth furnaces, an operation usually necessary annually or oftener, involves handling 300 tons of refractories for a 50-ton furnace. In many plants brick are now wheeled from car or storage to the furnace, thus involving a large amount of unnecessary handling. Lift trucks handling brick on skids in the plants where they are made are earning $8,000 to $12,000 a year over hand-wheeling costs, and it is our belief that a corresponding saving is possible in open hearth plants where a large number of furnaces is operated.

Ashes and Scale from Soaking Pits

An installation in a blooming mill was made at the soaking pits of a Pittsburgh plant some time ago. A truck equipped with a V-dump body was put on a wheelbarrow job that consisted of carrying ashes and scale from beneath the pits, up a heavy ramp, to dumping platform. For several years this equipment was in operation, earning a sum equivalent to the wages of 8 hand wheelers. Since the summer temperature beneath the pits frequently exceeded 130°, the change made it much easier to keep abreast of the job. It is necessary to note that a later demand for the space used by the ramp made it necessary to change again the method of handling—but reference to this installation adds a suggestive link in this account.

Handling Slabs of Steel

Slabs for plate rolling are handled with a specially designed chisel truck by the Cleveland Steel Co., where equipment of this kind has been in use for 9 years. This concern purchases slabs and receives this material in gondola cars. Weight per slab varies. From 4 to 6 slabs are carried at a time. They are unloaded from the railroad car by crane, placed on truck by hand and later removed from the truck by hand in the storage yards, about 150 feet distant. Each slab has to be handled at least twice—from incoming car to storage and thence to furnaces. From 30,000 to 50,000 tons of plate are shipped monthly from this plant—a figure giving an idea of the amount of work done by from 3 to 5 trucks.

Use in the Rod Mill

One of the most profitable uses to which the industrial truck has been put in this industry is the handling of rods and flat strip, including band and hoop stock. Several plants are using ram or crane trucks for this purpose, while others use tractors with trailers or lift trucks with skids. The final choice of equipment depends quite largely on individual plant conditions.

The difficulties involved in handling these materials are generally appreciated. A prime consideration involved in the selection of equipment

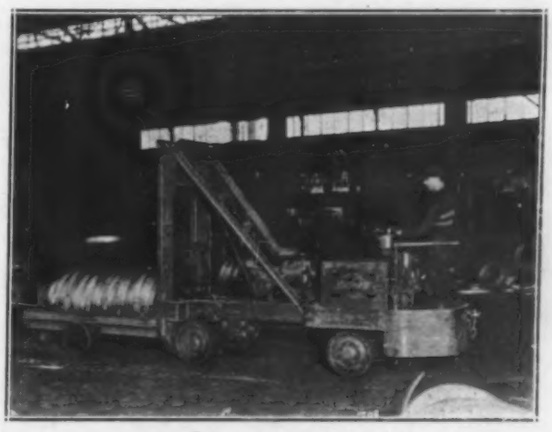

FIG. 3—Flat Strip Handling With the Ram Type Truck.

for this work is flexibility. Wire as it comes hot from the mill is heavy, bulky and awkward to handle—thus making it necessary to meet a set of special conditions. Further, for this work as for all other handling jobs in the industry, it is absolutely essential that equipment to be employed be sturdy. If men are to be taken from this work, it is necessary to substitute equipment which will perform so consistently that need for reverting to old methods will not arise, as obviously would be the case in the event of periodic breakdowns.

A few years ago, when it was first proposed to put ram trucks in the hot strip department of a mid-west steel mill for carrying the hot rods of metal to the cooling floor, the superintendent said flatly: "If trucks come in here, I go out." To him it seemed suicidal to attempt to do the job with machines so much larger than the hand trucks to which he had become accustomed. It is enough to say that the trucks came and the superintendent stayed. Six months later he said that "these machines can't be taken away except over my dead body."

The product from two hot strip mills had been taken care of formerly by four gangs of three

men each, and as fast as the hot rods came from the rolling mills they were wheeled away by hand. Periodically, it was necessary to shut down the entire plant to clear up the storage floor because of congestion, and a large amount of product had to be scrapped because of spoilage through this method of handling.

The installation of ram trucks for carrying away the rods did not solve the problem immediately because of the congestion existing at the time these machines were put into service. However, within a few weeks conditions began to improve; periodic shutdowns were eliminated and the earning power of the trucks became so high that they were paying for themselves once every month out of savings. Although the trucks used have now been in 24-hour service for two and one-half years, this record is being maintained at the present time. An idea of the capacity of these ram trucks may be gained by the fact that a random load, scale weighed, showed that 5,975 pounds was being carried.

On Sundays, when the rolls on the cold machines are changed, one of the ram trucks, fitted

FIG. 4—Heavy Castings Lend Themselves to Special Handling Equipment.

with a special key in the end of the ram, is used for handling them. In a Cleveland plant a crane truck is used for the same purpose.

Another novel use to which ram trucks are put at this plant is for carrying cold rolled strip in a special skid through the finishing department. This skid is built with ends of heavy sheet, with an opening cut below the center, so that when the ram is run through and the load is lifted, no pressure is brought to bear on the strip.

Handling in Nail and Bolt Mills

The crane truck has been found by several users to be well fitted for unloading, as well as for loading cars or other vehicles with rods of wire. A large manufacturer of nails, rivets, etc, found that such a machine saved 80 per cent over the cost involved in handling wire manually. Formerly it was the custom to handle bundles of wire weighing 150 pounds, but with the aid of mechanical equipment of this kind, it was found possible to handle 300-pound bundles without difficulty. Consequently, every department in the plant has been affected.

Operations have been improved in wire drawing, nail and rivet making and in the annealing and galvanizing departments. The machines used are practically automatic in operation, so that the only task for the operator is to start the wire going through the machine and to remove the finished material. Therefore, by substituting 300-pound bundles for 150-pound bundles, the machines have to be charged only half as often, the cost of charging is cut in two and since it takes more of the operator's time to start the wire through the machine than it does to remove the finished product, this cost is more than half of the labor required in manufacturing. As machines have to be shut down under the new system approximately half as often as previously, the increase in capacity is apparent.

At a plant producing hoop stock and cotton ties exclusively, the product is carried from machines to storage or direct to cars on skids. The point to be made in connection with this installation is that the entire product has to be shipped without benefit of a loading platform. The high lift truck, readily carrying its load to the level of a box car door, makes the business of shipping easy to accomplish. Doors have been cut through the building, at which cars are spotted so that the tie-in of the plant to the railroad is simple.

In bolt, rivet, automobile, sundry and small hardware manufacture, need arises for handling material in tote cans, frequently at high speed. Tote cans can, of course, be placed on a trailer or on the platform of a standard truck by hand, or by a built-on crane. In a plant where a comparatively small amount of tote can handling is necessary—this material happens to be steel chips —a crane truck is used for the work.

Moving Tote Cans and Tumbling Barrels

Formerly 9 wheelers were kept busy all day in disposing of material. The distance from the plant to the siding on which the car was placed that carried these chips away frequently exceeded 1,000 feet and always included a curving up grade of 6 per cent, 40 feet long. When crane trucks were placed in service, primarily in other operations, they were assigned the job of removing this chip material. Two trucks, two drivers and two helpers now do the job in 20 minutes that formerly required 8 man hours a day.

Plants handling large amounts of material in tote cans have found that a special designed truck is particularly useful. This is built to lift the can with arms that clinch it just under the top rim One such truck working mainly in the hot bolt department of a Pittsburgh plant saves approximately six men per shift in this work.

A recent development in this kind of handling has been accomplished by a hardware plant that handles materials in one ton batches in tumbling barrels. Parts are carried in this way either to pickling or shipping.

Handling pipe fittings and small iron or steel sundries is occasionally improved by the use of a magnet sling from a crane attached either to a low lift or straight platform truck. Power is sup-

plied from the batteries of the truck and the magnet is used for loading or unloading as is commonly the case, on a larger scale, in handling pig iron.

This use of the electric naturally introduces another problem frequently met in the same plants. The storing of cases and kegs in warehouses, prior to shipment, constitutes an operation that is wide open to lost motion. Sometimes hand trucks are used with portable tiering machines, sometimes a tramrail system is employed. Beyond question, either of these methods of handling has applications in which lower costs can be shown than by any other method.

The tiering truck, however, has come into favor in many plants for doing this work. The Bethlehem Steel Co., for instance, is reported to be using 7 machines in its storerooms at the Bethlehem plant. Carrying its load of 2 or 3 tons to heights of 8 feet, this machine, having all of the flexibility of an ordinary low lift truck is often able to make large earnings. From 8 to 10 men per unit appears to be average experience with this type of equipment in warehousing, although there is record of such a truck earning $10,000 in an afternoon.

This happened several years ago. The machine was purchased for use in a Pittsburgh plant where spikes, bolt plates and other railroad iron, made at another point, were stored prior to shipping with rails made locally. A large shipment on a foreign consignment was imperative by 3 p. m. of a certain day if the contract, with a forfeit of $10,000 for failure to deliver on time, was to be kept. The rails were ready, but the iron had not been received. On this day a new truck had gone to work. Along about noon the shipment of bolts, spikes, etc., showed up. The truck made it possible to transfer this freight rapidly enough so that, as the story goes, the rails could be sent on time.

Forge Shop Practice

Hot heavy handling in forge plants presents a type of service for which low lift trucks of high capacity (usually 3 tons or more) have proven their fitness. A manufacturer of automobile crankshafts and cams has found that although congestion about the forges is heavy, the electric has provided a satisfactory means for moving stock through the plant. Sheared lengths are carried to the pre-heating furnace near the tipping forge, thence the stock is moved to the various forging furnaces. Following forging, the semi finished shafts and cams are moved to a cooling area located partly in one section of the storage yard and partly between the heat treating plant and the pickling and shipping buildings. After cooling the forgings are taken first to the straighteners, then to inspection, to final trueing and to the heat treating furnaces. Following treatment the product is moved across to the pickling tanks located in a building adjacent to that from which outbound shipments are made. This cycle is continuous and there is a minimum of back flow of material once it has left inbound cars. The average trip made by every forging probably covers between 2,000 and 2,500 feet and includes not less than 13 handlings.

The elevating platform trucks used for this handling carry from 2 to 3 tons at a trip. The oldest of these machines (seven are in use) has stood up satisfactorily since 1920, when it was purchased. The skids used are of all metal construction. The loads carried are frequently hot; the speed at which the trucks are run is very high; the hours of daily service vary from 8 to 16 with battery changes approximately once in every 7 hours of running time. The saving directly effected by each is figured at approximately the wages of 18 men.

At another plant where pressed steel wheels are made, one of the most remarkable savings that has come to my attention was made. An industrial railway system was replaced by 1 tractor, 110 5-ton trailers and 1 lift truck. The innovation made it possible to keep all material on wheels at all times. The equipment paid for itself in addition to plant alterations (removal of tracks and substitution of paving) within a period of six months. This works out to a net earning capacity per unit of approximately $25,000 per year. Handling car wheels, where a considerable volume has to be transported, has proved to be an operation for which a special truck with a chisel lift attachment has proved fitted. This truck carries 4 or 5 wheels at a time, turns in its own length and depending upon battery voltage, as in the case of all industrial trucks, operates at speeds of from 4 to 12 miles per hour.

FIG. 5—Sheet Handling With Tractor and Trailers on Loading Floor.

In obtaining a reasonably comprehensive picture of the electric in this branch of the industry, the experience of such a plant as that of the Detroit Steel Products Company is helpful.

The problem first faced by the executives operating this plant was that of reducing the cost of moving automobile springs from the main floor level to that of the shipping platform, several feet higher. With hand trucks, eight men working hard, managed to handle about 90 tons per day. It was decided to install an electric lift truck, having a rated capacity of 3 tons. With some trepidition, the building of an adequate ramp was authoried for this truck to operate over. This ramp was 34 feet long, 7 feet wide and on a grade of 9 per cent. Construction was of concrete paved with wooden

blocks. The foot of this incline is approached by a sharp turn, necessitating a standing start.

Figures that indicate what this truck has accomplished in ramp work alone follows: Trips, 32; average load, 2.78 tons; number of loads, 32; men directly released for more productive operations where they were needed, 5. At every trip this truck carried its skid load directly into the freight car being loaded, thus keeping the labor of rehandling in the car at a minimum.

After a test of three months, during which time the truck was tried out in handling about the shop, as from shearing machines to presses, from presses to heat treating furnaces and from assembly to storage, it was decided to purchase another unit for doing this work exclusively. To provide open aisles for movement through the main section of the plant, it was necessary to move four

FIG. 6—The Tiering Truck Used for Stacking Kegs, Cases or Skids.

forging furnaces. Despite this, the savings effected during the following twelve months totally paid for all these changes, as well as for the complete equipment, including fixed charges.

The performance of the truck assigned entirely to work on the level floor is indicated by these figures: Tonnage handled per 9½-hour day, 373; number of loads, 163, and number of lifts, 218; average weight of load, 2.29 tons; distance traveled, 8.1 miles.

In order to eliminate all unnecessary rehandling in the plant, 350 steel frame skids are used. All material in process is kept on these skids between operations. As a consequence, the net cost of material handling, considering the entire spring plant, has been decreased 30 per cent.

Tractor-Trailer Method for Tie Plate Handling

The manufacture of railroad tie plate involves only a few handling operations but here, as in every other branch of the industry, there is a high differential between doing the job in the modern way and in the way that has been followed for the past quarter century or longer. B. F. Handloser, assistant general manager of the Dilworth-Porter Co., Pittsburgh, is responsible for the introduction of the tractor method in the plant of this company.

From 250 to 300 tons per day represents the capacity of the tie-plate division of this plant. The handling necessary involves the movement of most of this tonnage from punch presses to storage and from storage to loading station—a total distance of between 400 and 500 feet. These operations were formerly conducted by means of an industrial railway system with turn tables sprinkled about promiscuously. A gang of 15 men was required for handling the railway cars.

When the tractor was put in about two years ago, 16 trailers carrying 5-ton loads were purchased. At the time the change was made the plant was paved with a special flooring. At present the tractor with a crew of 7 men, is taking care of the entire plant—moving material at the rate of about a ton a minute during the working day of 10 hours. A special jaw coupler has been attached to both ends of the tractor, thus allowing handling trailer loads by pushing or by pulling. The racks on which the tie plates are placed at the machines are complete in themselves, and are equipped with eye bolts, for crane handling over long distances. In the yard where cars are loaded a bracket crane picks up this rack, swings it into a gondola car and drops it to ease off the grapple which is unhooked by the tractor helper. The rack is then pulled clear, placed back on the trailer and is ready to be returned to a machine station.

By this method it has been possible to eliminate rehandling altogether. The net saving at present is known to be equivalent to the wages of eight laborers. In the period during which the equipment has been operated no mechanical difficulties have been encountered with the tractor. The trailers have given some trouble due to faulty bearing construction, but this is being overcome by replacement with a heavier bearing of proper design.

Sheet Mill Service

The handling of black sheet, plate, etc, has perhaps received more attention on the part of manufacturers of electric truck equipment than any other series of operations in this industry.

For some jobs, where the sheets are large, the elevating platform truck with skids is used; on others the tractor-trailer method has worked out satisfactorily; on at least one job the crane truck with a special cradle attachment is used for handling. When tin plate is the commodity to be transported, several specially-designed trucks become available—two of which have been designed particularly for handling this commodity.

At one plant where six men were formerly used for pushing buggies loaded with 3 to 4 tons of sheet—a distance of 100′-150′ and including a slight upgrade, a single tractor proved its ability to move as much tonnage, in 5-ton loads, as previously had been handled by 22 men.

A typical instance of the performance of 2-ton elevating platform trucks in similar service is

provided by the experience of one of the largest concerns in the business. Over a period of 6 years, in 24-hour service, these trucks averaged to handle 17,708 tons per year by scales records. Each load weighed, however, had to be moved at least twice and usually three times. Most of this material was in the form of automobile black sheet 36"x72". The trucks regularly carried loads 50 per cent over rated capacity. The average repair cost was between six and seven cents per truck per 22-hour day. The distance traveled varied between 200 and 500 feet.

It is in the warehouse of this plant that the crane truck previously mentioned is used. An adjustable cradle has been rigged for handling loads that vary in sheet size. This consists essentially of an I beam, 3 cross members traveling lengthwise, each of which has a right angle under arm at each end, which is used for sliding under the load. Six points are thus provided for supporting the weight to be lifted.

A projected development of importance in this connection is the use of the 10-ton capacity lift truck. In automobile plants sheet is already being handled in this way and plans are now under way for shipping this material on skids so that no rehandling will be required from the time it leaves the stockhouse of the plant, where it is made, until it reaches the point of use in the plant of the purchaser. The possible saving to be effected through the general adoption of such procedure hardly requires comment. An important consideration in this connection is that a large percentage of the railroad cars in which sheets are received have the ends badly damaged and the rejections of spoiled sheets due to shifting within the car sometimes introduce prohibitive costs to supplier and carrier.

For carrying heated blanks of sheet from furnaces to presses the Hydraulic Pressed Steel Co, Cleveland, uses a high lift truck with a platform of firebrick. Although this haul is 400 feet long, the truck keeps two heating furnaces busy. The steel is 40 carbon and so it is evident that any appreciable cooling would have a serious effect in making brake drums. Actually less than ½ per cent of the drums made are rejected. The use of this truck in this way made it possible to avoid expensive alterations in the plant that otherwise would have been imperative.

At this same plant remarkable success has been experienced with push tractors and balanced type trailers for handling bars—and later in process for handling side rails, cross members and other parts going into automobile frames. All incoming steel is placed on these trailers as received and carried to machines on them. As each operation is performed at the various machines, parts are replaced on the trailers so that material is never laid on the floor for rehandling.

Eighteen tractors and 1,200 trailers with 56 men have maintained a production of 40 carloads a day —where previous to the advent of this system 250 hand truckers were needed to keep sufficient material moving to get out 20 carloads per day.

Tin Plate Handling

At the risk of getting the cart before the horse in discussing the handling of tin plate, three instances of saving will be cited before specifically pointing out how the electric industrial fits the handling problems of this branch of the industry.

A concern formerly spending $5.75 per car for unloading tin plate has reduced this figure to $3.25 through the use of a special fork truck equipped with a jaw clamp. Where the haul from car to storage is considerable, the truck loads one or two trailers, pulls them to storage, unloads them and returns for another load. Manual handling required is negligible.

A tin can manufacturer uses a slightly different type of truck for a similar operation. A 25-ton car is unloaded and the plate is moved to storage 80 feet distant, in one hour, with one man and a helper. A car of 33 tons is unloaded, transported to basement, using an elevator for the drop, moved a total distance of from 160 to 200 feet, stacked in piles 50 boxes high, with a crew of 2 men, in

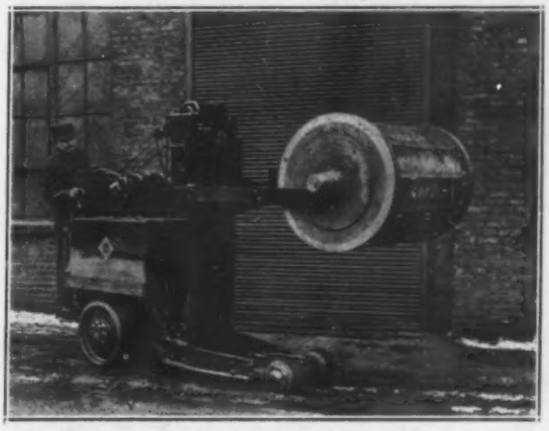

FIG. 7—Moving Castings in Tumbling Barrels With High Lift Truck.

3 hours' time. The machine is at present earning approximately $6,000 a year net, but the operations are still new, and it is expected that minor improvements in working conditions will result in higher earnings.

In a test made with still another type of truck in this service, the total cost of handling 134 tons per day worked out to be $10.50—a cost of 7.83 cents per ton, or 34.25 cents per 100 base boxes.

The use of the tin plate truck is still limited in the light of opportunities that exist for its profitable application. These opportunities, some of which exist in practically every plant, include:

(1) Handling black sheet from openers to finishing mills.
(2) Handling black sheet from finishing rolls to annealing pots.
(3) Handling black sheet from annealing pots to picklers.
(4) Handling bosches.
(5) Handling tin plate from tin stacks to sorters' benches.
(6) Handling tin plate from sorters' benches to checkers.
(7) Handling tin plate from checkers to slitters.
(8) Handling tin plate from slitters to packers.
(9) Handling tin plate from packers to railroad cars, or
(10) Handling tin plate from packers to warehouse.
(11) Handling tin plate from warehouse to cars.

The unit loads that can be readily handled with the truck run from 2500 to 5000 pounds. These units are separated by 2"x2" wooden or metal strips. A lift of 53" is the limit for trucks designed to work in and out of 6'x3" freight car doors or 62" for 7' doors, but trucks for warehouse service exclusively handle loads to heights of 7 or 8 feet.

Sometime ago a survey was made to ascertain the average cost of handling tin plate, with hand

FIG. 8—Pot Charging With This Truck Becomes an Inexpensive Operation.

trucks, at hourly or piece rates, manually as against handling with a fork type truck. These figures are on the basis of 100 base boxes.

	Hand trucks	Power truck
Handling loose tin plate in and about plants	14-16c	4½c
Handling loose tin plate from plant to car or vice versa	16-19c	8½c
Handling boxed tin plate in and about plants	12-14c	4½c
Handling boxed tin plate in and out of cars	15-17c	8½c

This same survey points out that definite possibilities exist for lowering the per ton cost of packing; that this could be decreased as much as 50c per ton by replacing the average 1¾ base box holding 175 pounds with a box of the same sheet size to hold a ton. Should this idea prove sound, and be generally adopted, with 1,400,000 tons of tin plate produced annually, a cut of $700,000 from this source is not impossible.

In this outline of the handling problems of the tin plate industry no mention has been made of the use of the electric for moving bosch trucks. The installation of two tractors at one plant having a sheet tonnage of between 300 and 350 tons per day, has replaced 7 men. The work consists of handling the bosch trucks loaded with pickled sheets from the pickler to tin stacks and returning the empty trucks to the pickler. Since it is necessary to keep the sheets in the bosch covered with water, there is considerable slopping when the trucks are moved by hand and in addition to making the floor slippery, it makes the clothing of the men wet and naturally it is difficult to keep men in cold weather.

Since the installation of the tractors the slopping has been eliminated. Under the present system one tractor operator and his helper move 100 bosch trucks to stacker and back—a total haul of 400 feet, in 12 hours.

Within the Foundry

There are a few handling operations, common in the foundry industry, that border so closely upon the field in which you are primarily interested that brief mention of them would seem to be in order.

Three such operations that I should like to bring to your attention are: (1) the handling of pig iron; (2) the handling of ladles; (3) the handling of annealing pots—because these three jobs typify the solution of difficulties that may arise in other branches of the industry.

As you know, the business of pouring in foundries is frequently a manual operation all the way. Sometimes cranes or a monorail system are used for primary distribution of the metal—a large ladle being used and the distance that the small ladles have to be carried being thus lessened.

For some time there has been a demand for a ladle carrier of reasonable capacity that would be completely mobile and whose use would involve no special hazard as from slopping. As an answer to this need a skid carrying a 2500-pound ladle has been developed and used in connection with a standard low lift truck.

One of the foundries of the U. S. Radiator Co. uses two trucks in this way. By releasing overhead crane equipment for other jobs, it has been found possible to increase the capacity of the foundry by 30 per cent. The American Seating Machine Co. has replaced an industrial railway system with 5 trucks, which run off a 40-ton heat in 3 hours.

The handling of pig has been mentioned. The development of a 10-ton capacity low lift truck is

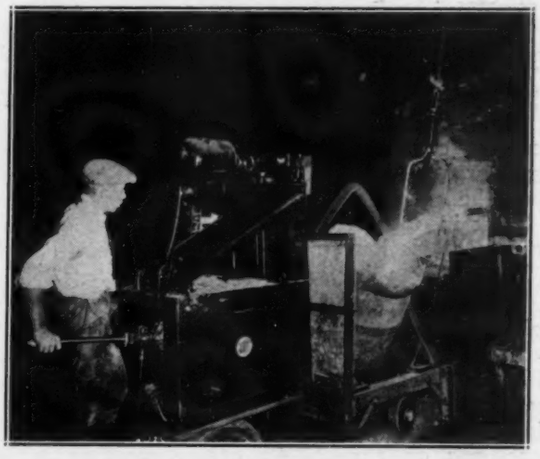

FIG. 9—Carrying Iron in Special Ladel Skid is a Successful Accomplishment.

making it possible to reduce the handling required for charging to a minimum. At one foundry such a truck, working only an hour a day, is earning $28.00 in this service over methods that were already more highly developed than those commonly in use in the industry.

The handling of pots in and out of annealing furnaces has presented unusual difficulties in the past. The labor for operating this department of a 25-ton

capacity malleable foundry frequently runs from 12 to 15 men.

At a plant where 4 special pot handling trucks are used for this work, 2,500 tons of material are moved every 24 hours. For moving this amount of material—equivalent to the capacity of fifty 50-ton railroad cars—a power cost of only $4.00 per day is involved. Because these trucks can work furnaces at a temperature of 700°-800 , it is possible, through their use, to obtain a much higher output than is

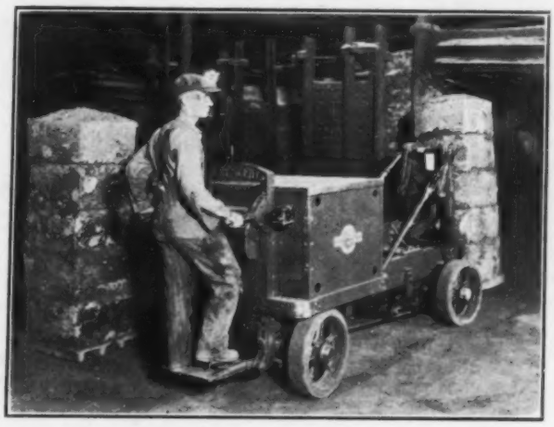

FIG. 10—Charging Pots in Annealing Furnaces.

the case when the furnaces have to be cooled sufficiently to work manually. A saving of from 5 to 15 men per truck of this type is generally found.

Throughout this account references have been made to savings in terms of men per unit or in terms of net earning. One company that builds electrics surveyed 15 plants in the Pittsburgh district about three years ago—plants that use one or two electric units and found the following averages to hold:

Maximum saving in per cent per plant	79
Average saving in per cent per plant	52
Maximum number of men saved per plant	18
Average number of men saved per plant	7½
Maximum saving per year on investment	345
Average saving per year on investment	270
Maximum saving in per cent per unit	75
Average saving in per cent per unit	29

It has been difficult to isolate average total fixed charges per unit in various operations, but the most reliable figures obtained show that even in heavy service, this charge rarely exceeds 60 cents per hour and that 50 cents is a reasonable average on all installations except those in which unusually difficult operating conditions have to be met.

In concluding this summary of the industrial electric application in your industry, a few unusual applications of the equipment should be pointed out. The crane truck has proved especially valuable in the service of maintenance departments—each unit saving 35 men in one plant. Pipe laying was expedited in a Pittsburgh steel plant through the use of such a unit. At another plant a basket in which the electrician works while trimming are lights is handled by a crane truck. A high lift truck equipped with a plow, has proved a valuable means of clearing narrow runways of snow in winter. Smaller plants use the electric to spot freight cars in the absence of a locomotive. Heat treating plants substitute long forks for a straight platform on the high lift truck and decrease the labor required for charging carbonizing furnaces by 15 men per unit employed. The dump body attached to any platform makes it possible to handle bulk materials.

The advantages gained through the application of this or any other equipment designed for similar purposes depends not only upon direct saving in payroll expense, but also, to a very large extent, upon other factors. An automobile manufacturer increased production more than five times in a manufacturing area only 33 per cent increased, and with a decrease in storage area of 25 per cent. A very large concern building agricultural implements has stated that one of the principle savings made comes from decreased inventory costs through keeping material in platform containers at all times. Many plants have experienced a decrease in labor turnover as a consequence of the substitution of labor aiding electrics for back breaking hand trucks—principally for the reason that this equipment does away with difficult manual jobs. In such practice as that cited at the nail plant, where handling costs were reduced 80 per cent—which, unfortunately has burned since this data was obtained—the equipment made it possible to alter process operations to great advantage.

Finally, let us take note of the fact that transportation within industrial plants in this country is costing $3,000,000,000 a year. Many millions of the total are chargeable to the handling operation of the iron and steel industry. By taking full account of existing methods in the light of available equipment, the present trend toward lower handling costs can be accelerated very greatly. In the progress made the electric industrial truck is certain to play an important part.

Acknowledgment

In the development of this outline, invaluable assistance has been rendered by many men in the industry who have made special studies of transportation problems. This list includes Mr. Bert Lawrence, American Steel and Wire Co ; Mr. B. S. Handloser, Dilworth, Porter Co.; Mr. J. A. Teach, Minneapolis Steel & Machinery Co.; Mr. M. J. Konston, Detroit Steel Products Co.; Mr. J. W. Cox, Erie Malleable Iron Co., and Mr. Pearson, Clinton Iron & Steel Co.

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A Discussion on Refractories for Use in Steel Plants*

By M. C. BOOZE†

THE problem of obtaining suitable refractories for industrial use is becoming one of general interest and is receiving more attention at the present time than ever before. This is evidenced both by the frequent demands for more resistant materials and by the comparatively large number of investigations on the subject that are being conducted by manufacturers and consumers. It has been stated on more than one occasion that the present difficulties are due to deterioration in quality of the available materials. It is admitted that in isolated cases deposits of raw materials have been exhausted and others used which are inferior, but to one familiar with the situation it is plainly evident that this condition is not frequently met with. Even in Pennsylvania where the greatest quantities of clays have been mined geologists estimate that the fire clays **in sight** are sufficient for from 25 to 50 years, and that the undeveloped deposits are sufficient in extent to provide for an additional period of even longer duration. In Kentucky and especially in Missouri, where fire clays have only been utilized in large quantities within comparatively recent years, the clay resources are very large, as they are also in many of the more western states. This is even more true with raw materials used in the manufacture of silica brick. In some cases quarries have been worked out and deposits of accessible floe rock depleted, but high grade material for silica brick is available in such quantities in a number of districts that there is no fear of exhaustion for a long period of time.

There are at the present time over 200 companies engaged in the manufacture of refractories in the United States. These are so located that competition for business in the more important consuming districts is keen and this in itself insures as uniformly high quality as it is commercially feasible to obtain.

The present condition has not come about because of a reduction in quality of refractories, but rather to an increase in the severity of service requirements. That the requirements have become more exacting can hardly be doubted, as there is ample proof for the statement in the records of furnace yields in all lines of industry. This is especially true in the manufacture of iron and steel where quantity production is the keynote because of its direct bearing upon costs. While the problem of suitable refractories is of importance to the iron and steel industry, it is no more so than to the manufacturers of fire brick because of the fact that steel plants and their accessories utilize as much as 50 per cent of all refractories manufactured. As the total production in this country each year approximates 4,000,000 tons and has a value of about $60,000,000, it can be seen that the amount consumed in the manufacture of iron and steel is no small item. Computed on the basis of average life, the cost of the refractories alone is not a large percentage of the total cost for producing steel. When the labor costs and idle furnace charges are also included in the costs for refractories, however, the figure may become an important one. It becomes most significant when premature failure occurs with a considerable loss of production.

There are two major problems relating to refractories for use in iron and steel furnaces that are confronting the manufacturers and consumers today. The first of these is the obtaining of better service from the commercial clay and silica brick that are now available, and the second is the development of suitable material for more severe furnace conditions.

It might seem that these two problems were inter-related and one was merely a continuation of the other, but this is not the case. The possibilities of radical improvements in the common refractories are not promising and it can hardly be expected that these will be so altered as to serve efficiently under conditions which are appreciably more severe than those existing in industrial furnaces today. For an illustration, the use of oxygenated air in open hearth furnaces would probably result in roof temperatures much higher than are now found and the service would, accordingly, be too severe for the best silica brick that could be made. To meet the condition it would either be necessary to make use of radically different material or to alter the furnace design or operation to such an extent that basic oxides did not come in contact with the refractories.

Improvement in service obtained from the common refractories may be brought about in several ways. The refractories themselves may be bettered, better selection may be had. or the conditions of service may be suitably altered.

Improvement in Quality.

It is possible for every manufacturer of refractories to carefully select raw material which will, when properly treated, result in products better than the average which he produces. By such selections he is able to eliminate some impurities with consequent improvement in refractories or to take advantage of certain desirable physical or chemical properties. Such selection, however, involves careful examination and the rejection of a large amount of material. Clay containing readily observed foreign matter is thrown out regularly at the mines and to further reduce the content of impurities it is necessary to examine each piece individually and even to reduce the lumps to comparatively small size. Such sorting is resorted to at some plants for special products, but the practice is not general

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The two major impurities are silica and iron oxide. In some cases these are concentrated in veins or pockets, but they are more frequently scattered in a random fashion throughout the clay deposit. In the latter case hand-sorting is not appreciably beneficial and in no event is it possible to remove all of these impurities. Removal of these materials by other methods have been considered, but do not appear to be practical. Washing would not improve flint clay unless very finely ground because of its non-slaking properties and the finely ground material would not be suitable for many products without further processing. Removal of some of the iron oxide is possible by washing, electromagnetic, or electrostatic treatment. Any of these methods again requires fine grindings and even then the separation is not very satisfactory. Electrical separation methods have been tried on dry clays and the experiments have shown that a large amount of clay is removed with the iron and that the cost is almost prohibitive for fire brick. Considering the fact that flint clays are the important constituent in fire clay brick, that this material has physical properties making it particularly difficult to treat, that a large tonnage of low priced material is involved, and that the amount of benefication to be expected is small, it does not appear feasible to adopt purification methods. Fire brick, whose purity is comparable with that which would be obtained by efficient purification methods used on fire clays, are now on the market at a price probably not greater than would be required for washed or treated clay brick. Their limited use is an indication that such products are not economically feasible at the present time for a major part of the furnace requirements.

Silica Brick

Silica brick are made from rock containing from 97 to 98 per cent SiO_2. They are almost invariably bonded with two per cent of lime and given a sufficient heat treatment to bring about inversion of nearly all of the quartz to cristobalite and tridymite. Silica brick from the roofs of open hearth furnaces have been examined after campaigns of various lengths by a number of investigators who have found that the brick, after use, contain several unlike zones. At the cooler end the brick remain in their original state, while at the hot ends the lime and alumina are lower and the iron oxide higher than in the brick as originally installed. In the intermediate zones the contents of lime, alumina and iron are all higher than in the original brick. This means that the impurities or fluxes have migrated from the hottest to the cooler portions of the brick, and if it were not for the abnormal concentration of iron oxide at the hot ends, due to deposition from the furnace gases, there would be an actual improvement in refractoriness. The amount of iron oxide deposited on the hot surface, however, is sufficient to greatly reduce the refractoriness and the softening point of the material at the surface is usually found to be well below the furnace operating temperature. The dripping point of uncontaminated silica brick is well above normal open hearth roof temperatures. Kanolt found that they became fluid enough to flow at about 3,100°F, and similar softening point temperatures are found for commercial products. Because of the fact that the normal impurities become reduced in amount at the hot face, it is very probable that the dripping temperature would be appreciably higher than that given if contamination were not a factor. There is not much question, therefore, but that the refractoriness of the commercial silica brick now available is in itself sufficient to meet the present day demands satisfactorily. The deposition of iron oxide, which is the real cause for dripping in the majority of cases, is, of course, beyond the control of the manufacturers of silica brick as is also the chemical properties of the silica and since these are the limiting factors in determining the safe operating temperature, there is little improvement open to the manufacturer in this direction. The porosity of the brick that are used may have an appreciable bearing upon the length of time that they will remain serviceable and this property is controllable within limits by the manufacturer. A brick which was impervious to iron oxide and fluxes contained in the furnace gases would be attacked only at the furnace. With porous brick the active fluxes are drawn up into the pores and solution speeded upon on account of the greater surface affected and the greater amount of flux brought into action. Dripping under such conditions takes place more rapidly if the temperature is above the flowing point of the products of reaction. Silica brick range in porosity between 21 and 30 per cent. Lower values are sometimes had by blending raw materials which differ in hardness or resistance to crushing, so that the gradation of particle size is partially controlled. There are practical, but definite, limitations to the reduction in porosity of these products, however, and a porosity value of 18 or 19 per cent represents about the greatest density that can be expected.

In addition to reaction with fluxes, failure of silica brick in open hearth roofs occurs because of spalling. In fact these two factors acting either individually or together are almost entirely responsible for ultimate destruction in this service. Spalling is interpreted two ways. To some it means breakage from any cause while to others the term implies breakage due to temperature changes or temperature differences. In this discussion the latter meaning applies.

Spalling occurs when the thermal expansions at adjacent portions of a brick or shape differ sufficiently in amount because of temperature differences to exceed the elastic limit and ultimate strength of the material. The sensitiveness to spalling under given temperature conditions is then governed by the thermal expansion characteristics and the elasticity. Silica brick are peculiar in that they contain silica in a number of crystalline forms, each of which has a typical and pronounced expansion characteristic. The rock from which the brick are made is very largely quartz, but this, upon being burned, inverts to cristobalite and tridymite. The transformation to these forms is sluggish and is accomplished in practice by burning at a high temperature and for a long period of time. The inversion is accompanied by a decided decrease in specific gravity and consequently an increase in the size of the product being fired. Under the conditions prevailing in the majority of kilns burning silica brick from 85 to 90 per cent of the original quartz changes to cristobalite and a small percentage of the cristobalite then changes to tridymite, the latter being the stable

form below 2,700° F. and cristobalite being stable above this temperature. The brick that are usually supplied for use in metallurgical furnaces are then largely composed of cristobalite with smaller quantities of quartz and tridymite and some silicates and lime, alumina, iron and alkalies. Upon being heated, cristobalite exhibits the characteristic of expanding very sharply and by a relatively large amount at a temperature of approximately 400° F. Tridymite does not expand as rapidly nor by as large an amount as cristobalite. Quartz expands gradually until a temperature of about 1,100° F. is reached when the expansion increases sharply. The rapid expansion of quartz at 1,100° F., however, is only about one half that of cristobalite at 400° F. Above a temperature of 1,100° F., all of the three crystalline forms described exhibit no sharp expansion or contraction characteristics. Therefore, considering only the spalling that might occur during the heating up of a new furnace, it would be preferable to make use of brick containing a maximum amount of tridymite rather than cristobalite. The difficulties involved in the manufacture of such products, however, are very great. The change from cristobalite to tridymite goes on very slowly and cannot be greatly accelerated by increasing the burning temperature because no tridymite will be formed above 2,700° F. and the present burning practice is not far from that figure. A high tridymite content would only be greatly beneficial during the period of heating up the furnace in which the brick were used because open hearth temperatures are above the range in which tridymite is stable. Open hearth roof brick after service are found to consist of cristobalite at the hot and cold ends with tridymite in the intermediate zone. If the brick were originally composed of tridymite, they would be the same after being used as those now supplied except that there would be no cristobalite at the cold ends. The formation of tridymite in a zone adjacent to one of cristobalite may result in some strain due to the difference in specific gravity between the two, but this difference is small and the graduation from one zone to another is not sharp

From a spalling standpoint, the normal hard-burned silica brick are less to be preferred than those of softer burn which contain large percentages of quartz. Where the furnace temperatures are high, however, the inversion from quartz to cristobalite and tridymite will take place in service and soft burned brick will increase in size. If the quartz content is high, the permanent expansion may become sufficiently great as to cause serious disturbances of the furnace walls or roof. This factor is of such importance that the use of hard burned brick becomes necessary in coke ovens and large furnaces in spite of the pronounced spalling tendencies. This objectionable feature is offset partially, at least, by the smaller amount of mechanical breakage occurring because of movement of the walls or crown. The hard burned brick are much stronger mechanically than those that are soft burned and the breakage is further reduced for this reason.

It is frequently stated that silica brick will not spall noticeably if kept above a red heat. This is true but does not necessarily apply to brick which are heated only on one end and apart of which are below the critical temperatures previously mentioned. A recent investigation has shown that the temperature wave, which travels through a silica brick when the temperature is altered at the hot face, is damped as it proceeds toward the cold end and for practical purposes may disappear. However, with very abrupt and pronounced changes the temperature of the portion of the brick which is within the critical temperature range may also change and produce spalling even though the hot face remains undamaged.

It has been previously stated that fluxes migrate from the hot face of a silica brick in an open hearth furnace roof to a zone nearer the cold end. When spalling takes place and a large piece of a roof brick falls out, the surface then exposed to the high furnace temperature is of low refractoriness due to the abnormal concentration of impurities and this immediately begins to drip or "bleed" as it is sometimes called, and a hot spot soon develops. The spalling of one brick also accelerates spalling of surrounding pieces and unless repairs are promptly made, may result in premature failure of the whole roof. The roof brick may also be cracked or crushed when expansion is taking place during the heating up period and, because of pieces falling out later, seriously shorten the furnace life. Good usage demands that the brick be laid with the greatest of care, that the initial heating schedule be very slow, and that the stresses due to expansion be kept low.

Because of differences in the specific gravities of quartz cristobalite and tridymite, it is possible to determine with a fair degree of accuracy the amount of quartz inversion (and consequently the effectiveness of the original burning treatment) with a simple specific gravity determination. This method is much more rapid and frequently more accurate than a microscopic examination. The specific gravity of quartz is 2.65, cristobalite 2.33 and tridymite 2.27. If the specific gravity of the burned product is above 2.33, it is probable that some quartz is present, although this is not necessarily true since silicates of relatively high specific gravity are also present in small amounts. If the specific gravity is below 2.33, it is still possible for some quartz to be present, although it must be considerably less in amount than the tridymite content. The silica brick that are commonly used today are usually burned sufficiently hard that the specific gravity is below 2.38 and in some cases is as low as 2.32. A low specific gravity figure does not, however, insure that brick are properly burned. If inversion has taken place too rapidly, the finished product will be found to be oversize with relatively low mechanical strength and high porosity.

It has not always been the practice to burn silica brick as hard as they are today. The practice has been developed to meet the demands of large installations and high temperature operation and has reached the stage where further development appears to be neither feasible nor necessary.

Selection of Suitable Materials.

The proper selection of refractories for various service conditions is a difficult problem and is usually solved only after a number of experimental trials have been made. The difficulty arises largely because of a lack of definite knowledge of the service requirements, because of their complexity, and because of the general tests for refractories may not give results which are applicable to the conditions

at hand. There are many instances, however, where an improvement in service may be had by better selection. Fire brick are frequently bought on the advice of a mason who judges not by the service rendered so much as he does by the ease with which the brick may be laid, or by their nearness to a mental "standard" which is defined only by color, texture, and ease of cutting. There are many purchasers of fire brick who still insist upon obtaining soft, coarse, light colored brick in the belief that these properties are indications of high refractoriness and others who demand dark colored products with the thought that this insures brick that are hard burned. Fire brick are also occasionally purchased on such impractical specifications.

The best method of selection is by trial under actual conditions and this is usually the most satisfactory even though it involves the keeping of accurate records and requires a considerable amount of time. Where selection is accomplished by trials it is sometimes the case that the service records are misleading because of inaccuracy, because the samples have been placed in the wrong position in the furnace, or because the furnace is operated differently at one time than another. These conditions are, of course, governable and must be given attention or fair comparisons cannot be made.

The physical tests for refractories are at best only approximations of actual furnace conditions and should be resorted to only when service trials cannot be made or in order to eliminate from further consideration products which are not at all suitable. The standard tests are not definite enough that they can be relied upon to indicate the better of two brands of brick which are of fairly similar characteristics.

The tests which are applied most generally are—

1. Fusion or softening point.
2. Chemical analysis.
3. Deformation under load.
4. Spalling.
5. Permanent contraction or expansion.

Fusion or Softening Point

This is normally made by determining the temperature at which the tip of a cone made from the ground brick or clay under test will bend sufficiently to touch the base in which the cone is held. In the standard test the rate of heating is prescribed, but since this partially determines the end point temperature, it is evident that the value obtained is not the "safe working temperature" of the material as is often assumed, but is only a figure by which a general comparison can be made with the refractoriness of another sample tested in a similar manner. The failure of refractories does not take place very often from fusion or dripping except where contamination with impurities from the furnace or fuel has occurred. The fusion or softening point has no direct relation to the behavior when in contact with fluxes, when under load or when subjected to many other destructive agencies, and as these may be and usually are the real cause for ultimate failure, it should be evident that the softening point is only of value in insuring sufficient true refractoriness and cannot be used accurately in a more general way.

Chemical Analysis.

The chemical analysis of a fire brick will give to an experienced man a general idea of the refractoriness. In spite of several investigations on the subject, however, there is no rule by which the ultimate refractoriness can be closely or accurately determined from the analysis. Since failure occurs frequently because of certain physical properties that are influenced only indirectly by the chemical composition, the latter should not be made an important factor in the selection of fire brick except for certain specific conditions. These conditions usually involve reactions between the fire brick and slags or material being manufactured as the major cause for failure. In the light of present knowledge and with such complex materials as fire clays, the effects of small differences in compositions are impossible to predict accurately. With extreme variations in composition, practical experience has shown certain differences in physical characteristics which bear upon the service rendered. Brick containing a high percentage of silica are often found to be more constant in volume and to deform less at medium temperatures than those that contain considerably greater percentages of alumina. The ultimate refractoriness, however, is less and the effect of fluxes is usually greater on the silicious brick than on the aluminous ones, so a comparison cannot be made on silica content alone. Again the silica content may be so high that no bond will develop and instead of being rigid under the load, the brick will be relatively weak. Highly aluminous brick may also be so processed that they will not shrink when heated and will support loads remarkably well. It is evident, therefore, that conclusions as to the suitability of fire brick drawn from chemical analysis can only be very general and that these should usually be qualified by other tests.

Deformation Under Load.

This test was originally devised to measure comparative "refractoriness" and as a means of determining in a simple way the relative suitability of fire brick for industrial furnace use. The conclusion that such use could be made of the test was apparently based upon the assumption that plastic deformation under load takes place because of the presence of low melting glass, that the amount of deformation is proportional to the amount of this glass, or its effectiveness in reducing refractories, and that vitrification, shrinkage, spalling, etc., are affected in the same way by the low refractory constituents as the deformation under load. The first assumption is true. The second is not as is shown by the fact that brick of open texture deform considerably more readily than those that are more dense, but otherwise identical. Further disproof of the second assumption is that brick which are hard burned and which contain a relatively large amount of glass deform less readily than when soft burned. The third assumption is also disproved by the difference in spalling tendencies between hard and soft burned brick, the latter generally spalling less and deforming more than the former.

In the majority of furnace walls the weight load is not over 10 pounds per square inch and there is a pronounced temperature drop from the inner to the outer surfaces. Tests have been made in which loads as high as 25 pounds per square inch have

been applied to fire brick columns nine-inch thick heated to a temperature of 2,800° F. on one side and insulated on the opposite side with 4½ inches thick of the best grade of insulating brick. In this test no appreciate deformation has been found even when brick were used which failed completely in the standard load test at 2,462° F. and under load of 25 pounds per square inch. An extensive investigation on the deformation under load of a large number of fire brick has shown that deformation does not ordinarily become important until a temperature above 1,200° C. has been reached and there are few furnaces where the mean wall temperature is above this figure and where the portion of the refractories that is below the deforming temperature is not sufficient to support satisfactorily all the load that the whole wall is required to carry. Where the mean temperature is abnormally high as may be found in insulated or especially thick walls, or walls heated on both sides, deformation under load may be highly important in which case a severe load test requirement is justified. Otherwise a load test requirement may even be harmful in that the brick which meet the test most satisfactorily are usually weak in other respects.

Spalling.

The test for spalling is usually conducted on fire clay brick by alternately heating the ends of samples of brick to a prescribed temperature and cooling them either in water or in a blast of air. The test which has been most generally used consists in heating the ends at 2,462° F. and then dipping in four inches of water. In another the temperature is only 1,242° F. with water dipping, while in a third the temperature is 2,900° F. with air cooling. The practice is also followed sometimes of reheating the whole samples at 2,550° F. for five hours before spalling. The value of this procedure is doubtful. Vitrification is a factor in the spalling of fire clay brick, and reheating at 2,550 ° F. will show difference between lots of brick in vitrification behavior if such differences exist to a pronounced degree, but since time is a decided factor in vitrification, this should be taken into account in the test rather than producing vitrification before the test is started. It is also common practice for manufacturers to furnish light burned brick where spalling conditions are severe, as they have found that better service is obtained in this way than from hard burned products. Reheating destroys the beneficial effects of light burning and is objectionable for this reason if no other.

When the water dipping spalling test is conducted it has been found preferable to dip in two inches of water rather than four inches. The former method produces more gradual loss and less erratic behavior than the latter. Dipping in four inches of water frequently causes the test brick to break in half, while true spalling usually takes place by corners and comparatively thin flakes breaking off.

Cooling in a spalling test by an air blast is preferable to water cooling, but requires a considerably longer time for the same amount of spalling. When dipped in water, cooling takes place along the sides as well as the hot face and the plane of maximum thermal stress is made to occur at a greater distance from the face than is normal in actual practice. With air the cooling can be better confined to the hot ends, although it is difficult to prevent some cooling on the sides when individual samples are tested. Present development is tending toward a spalling test in which the samples are tested not as individual pieces, but after being laid up in a wall or roof. This procedure has much to recommend it and a "simulated service test" of this kind may eventually find general application.

Expansion and Contraction.

Limits have been proposed for the permanent expansion or contraction of fire clay brick upon reheating at 2,550° F. for five hours with the thought that these determined the suitability or quality of fire clay refractories. It has since been found, however, that expansion may take place from other causes than the overfiring of clays and that brick would expand unduly in the test which were capable of giving excellent service. Secondary expansion, as it has been called, occurs from some other cause than overfiring. It is restrained by very light loads and under the comparatively slow rate at which industrial furnaces are initially heated, may be negligible or much less in amount than test results disclose. Permanent contraction is of course objectionable if it is sufficiently pronounced to disturb the furnace structure. The original burning temperature of fire clay brick is usually well above the mean temperature of the furnace wall where the brick are used and in this case shrinkage takes place only at the hot face if at all. Some shrinkage at the hot face is desirable if no relief for thermal expansion has been provided since otherwise the hot expanding ends are apt to be wedged together and pushed off.

Reversible thermal expansion is a property that has been given too much attention by the consumers of fire brick. To engineers concerned with the designing or building of furnaces the value for this property is important but because of the fact that the differences between various brands of brick in this property are relatively small and especially because other properties are so much more important, the consumer should best concern himself with this property when he is attempting to select from several lots of the same general type the best brand of brick for any particular purpose.

Slag Action.

Although erosion by slags is a very important cause for the failure of all classes of refractories, no test has been developed for slag action which can be readily used and which gives accurate results In the first test which came into general use the samples were either placed in a small bath of slag or the slag was held in contact with the brick surface while contained in a refractory ring cemented to the brick.

In the second test, the slag and refractory material were ground together in various proportions and the mixtures made into cones whose softening temperatures were then determined.

The first test is subjected to the serious objection that the slag soon becomes saturated with refractory material and no longer is chemically active but merely penetrates the pores. The tests thus become more a measure of permeability than slag erosion. The cone test measures only the tem-

perature at which a certain degree of fluidity is obtained by slag-refractory mixtures of definite proportions. In addition to the fact that there is not a true comparison of viscosity and that the latter influences the rate of erosion, the test is also subject to the objection that conclusions must be drawn from results obtained on arbitrarily selected mixtures without knowing whether or not these accurately represent the products of reaction as they would actually occur in service.

In service, refractories may be affected by certain ingredients which later enter into the slag and which are much more active than the slag itself. This is known to be true in many instances and is probably of more importance than is generally realized. Under these conditions, it is erroneous to conduct a test with the final slag rather than the uncombined constituents of the slag.

The attempts that are being made at the present time to develop new slag tests are directed along more logical lines than in the past. In nearly all cases these are devised to allow slag to come into contact with one surface of the test specimen while at a high temperature and the slag is replaced as it reacts with the refractory material and flows away. By this means the chemical characteristics and physical structure of test samples are both allowed to play their roles and there is promise of considerably more satisfactory results than have been had with other tests. Some difficulty is anticipated because of the fact that acceleration seems essential and if this is accomplished by abnormally high temperatures the results may be erroneous.

While all of the tests for refractories are more limited in application than is desirable they still serve a very useful purpose. When the specific conditions of service are known, properly selected tests will make possible the choosing of brick which at least will give average service where otherwise the choice would have to be made more or less blindly. The tests have been of particular value to the manufacturers of refractories and have thus indirectly benefited the consumers. It is with brick made from the same materials but differing in physical properties that the tests give the most reliable results. Many of the tests have also been worth while in insuring uniform quality and this item is of no small importance.

Metallurgical Requirements.

Metallurgical processes must be partially adapted to the refractories that are used if the conditions are severe and length of service is an important item because each class of refractory material has definite limitations and none of them possess a high degree of resistance to all of the agencies causing failure. For the greatest efficiency in a single furnace it may therefore be necessary to use several materials each for a definite purpose that the other cannot fulfill satisfactorily.

A discussion of the requirements for refractories is thus almost meaningless unless the properties of the available materials are taken into account at the same time. The spalling properties of silica brick, for instance, are certainly not included in any furnace requirements. The valuable service that they render is made possible by adapting the furnace operation to this weakness.

The requirements that are of the greatest concern to the manufacturers of steel are found in open hearth furnaces, blast furnaces, heating furnaces, regenerators and coke ovens. These requirements must be considered with the limitations of silica, clay, chrome and magnesite refractories in view as they are the only materials that are known to be usable and which are at the same time economically feasible.

The high temperatures of open hearth furnaces and their size make silica brick necessary. From the standpoint of spalling clay brick would be better but the latter would neither remain rigid in the arch nor resist the action of basic slag as well as silica brick do. Magnesite brick would be better suited in the furnace lining for resisting chemical attack but they would not serve because of their weakness when hot and chrome brick are unsuitable for the same reason as well as for their pronounced spalling properties and high cost. Of the silica brick, there is really only one grade available that is suitable for this service. Some differences exist between brands that are supplied for open hearth use but as a rule these differences are slight. Since the furnace requirements are such that the brick must be well burned and show but little residual expansion there is very little hope of bettering the spalling properties and as has already ben explained, the resistance to attack by the basic oxides carried in the furnace gases cannot be altered. Open hearth furnace operators cannot do more therefore than insure themselves of obtaining silica brick of the usual composition and burn.

Magnesite as well as chrome brick are required in these furnaces entirely on account of their resistance to the fluxing action of basic oxides. The magnesite in order to be the most resistant to reaction should be largely in the form of periclase and to produce this mineral form economically it is necessary that a flux or catalizer be present during the original calcining process. It is for this reason that iron bearing magnesite is used or that iron oxide is added to pure magnesite previous to dead burning for refractories. Magnesite brick have been made in quantities both from relatively pure domestic material and from imported calcined magnesite. At the present time for purely economic reasons the foreign material is very largely employed. There is little evidence of marked variation in the imported product and it also appears to be well burned. Differences that exist in commercial magnesite brick are therefore probably due very largely to differences in the methods of manufacturing brick from the dead burned grain which affect the porosity, mechanical strength and potential shrinkage. Where the brick are of average composition, suitability will ordinarily be established by a high specific gravity and a low porosity value.

Chromite from which chrome bricks are made is obtainable in several degrees of purity and with considerable differences in physical structure. Information on the effect of these differences is limited however and it is not definitely known what type gives the most satisfactory service. The chemical inertness of chromite to both basic and acid slags is marked and the material would be of great value if the hot strength were high and the spalling tendencies not so pronounced. On account of the wide

choice of raw materials some development of this product may be possible.

The properties of fire clay brick may be readily altered in a number of ways and there is a wide choice of clay refractories for use in blast furnaces, stoves, regenerators, and heating furnaces. In blast furnaces it is fortunate that where high refractoriness is essential, the hardness is not highly important and vice versa because it would be difficult to develop both properties to the maximum degree in a single product. Sufficient refractoriness cannot be obtained in clay brick to resist the highest hearth temperatures and the use of cooling plates in this portion of the lining will no doubt always be necessary. The usual blast furnace campaign is of such length that there can be little justification for pronounced dissatisfaction with the refractory lining. Premature failures have occurred, however, for which the brick were responsible and these indicate the need for some means of insuring uniformly high quality. It is a debated question whether the ultimate failure of a blast furnace lining is due principally to mechanical abrasion or to weakening of the brick by deposits of carbon, zinc, etc. In any event, greater mechanical strength should extend the life, and as this may be accomplished fairly readily by the manufacturer by increasing the hardness of burn, hopes are held for an extension in the life of these furnace linings. The objection has been cited that hard burning would promote spalling, but with care in heating up the new lining this should not be an item of importance.

Fire clay brick for stoves are not called upon to meet severe conditions and they have been known to last for priods of several years. Here, as in regenerators, the highest thermal efficiency may be obtained by the use of the densest brick. This is contrary to the opinion held by some practical men, but may be checked by experiment.

The problem in open hearth regenerators is to obtain brick which will not slag away rapidly and which may be salvaged when the regenerator is cleaned. Breakage is largely occasioned by rough usage at the time of cleaning and this indicates the need for dense, mechanically strong brick. High density will also be beneficial in resisting erosion and in increasing the thermal efficiency of the checkers. It is also necessary to make use of brick which have good refractoriness on account of the abnormally high temperatures that are occasionally found in the regenerators.

The type of brick to be used in heating furnaces varies with the conditions of operation. Where the temperatures are extremely high, refractoriness is all-important and a relatively short life can be expected. In others where the temperatures are high, but not excessive, good grades of highly silicious clay brick have been found to be very satisfactory. Refractoriness, constancy in volume, and rigidity while hot are the important factors.

In coke ovens hard burned silica brick are required not only to insure that a small amount of permanent expansion will take place, but also to resist the abrasive action of the coke. For high thermal efficiency and short coking periods, it is necessary to operate the ovens at high temperatures and to make use of thin walls. Under these conditions the high rigidity of silica refractories is an extremely important factor. The resistance to abrasion of a specific brand of silica brick is developed to the highest extent by low porosity, hard burn. and high mechanical strength, but the better of two products made from different deposits of ganister cannot be definitely determined by measuring these properties. Potential permanent expansion which may have serious effects on a long battery of ovens can be determined by measuring the true specific gravity as previously mentioned.

Developmnts of New Refractories.

The possibilities of notable developments with the common refractory materials are so far from promising that they need little consideration. There are a number of comparatively new materials, however, whose possibilities are not completely known and which may solve some of the present difficulties. These are silicon carbide, alumina in the form of corundum and diaspor, mullite, zircon and spinel. They all have the advantage of high refractoriness and most of them being of definite crystalline composition are rigid under load when hot and subject to little or no permanent change in volume when heated to high temperatures. Information as to their slag resisting characteristics is generally lacking. The greatest disadvantage is in their high cost and it is practically certain that were it not for this factor, many of the materials mentioned would be used very widely. It is some satisfaction to know that when the need for refractory materials that are more resistant than silica and fire clay becomes sufficiently urgent, such materials as those described are available in commercial quantities.

Since little betterment is to be expected in the common refractories and since more durable products are too expensive for general use, it is to be expected that developments in the immediate future for the purpose of extending the life of furnaces will be along the lines of new furnace designs and different types of construction. Air and water cooled walls are already making headway and the possibilities along this and other lines are believed to be much greater than is generally appreciated.

Open Hearth Roof Construction*

By W. J. HARPER†

In discussing refractories for open hearth roofs it is beyond the scope of the writer's experience and knowledge of refractories to discuss the chemistry of the refractory material and the reactions that take place in the refractories due to the conditions imposed by open hearth service. Therefore, the follow-

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†Combustion Engr., Donner Steel Co.

ing is merely a brief outline of the experience the writer has had in the application of roofs to open hearth furnaces.

It is, of course, realized that different conditions exist in all plants. Furthermore, the writer feels keenly the responsibility in endeavoring to discuss a subject that is so vital in the practical operation of open hearth furnaces and regarding which there is such a great amount of differences in opinion. The writer will, therefore, confine himself to the experience obtained in the application of roofs to one of the furnaces at the Donner Steel Company, Buffalo, N. Y.

This furnace is a 100-ton furnace, fired with coke oven gas and tar. Originally this was a tilting furnace, but for a number of years has been used as a stationary furnace. The furnace width from inside of front wall to inside of back wall is 18'4". The length from inside to inside of end walls is 74'8". We have been using the ordinary type of sprung roof, consisting of rings of 12" silica brick, the total rise of the arch being 26". There are no tie rods running across the furnace from front wall to back wall, all of the buck stays being tied together by girders, thereby providing a rigid binding throughout. The front and back walls are each 13½" walls. From end to end the arch is arranged with a slight knuckle over the ports, this knuckle projecting below the crown of the arch 15¾".

Over a period of years the average life of these arches has been 135 heats. In considering the increasing of the life of these roofs a great number of possibilities were taken into consideration.

1. The possibility of increasing the thickness of the roof from 12" to 15 or 18".

2. The re-arrangement of the binding, and the substitution of tie rods for the rigid girders.

3. The installation of a suspended form of roof.

The objections to the first consideration were that, while additional life might be obtained, due to the increased thickness of the roof, it was questionable whether the increased life would be in any way directly proportionate to the increased thickness and furthermore, it was felt that, due to the additional weight, the expansion would be comparatively greater and because of the rigid binding failure, might result without a substantial increase in life over the original form of roof construction.

In considering the second possibility considerable expense would be involved to change the binding and it was felt that if the binding was to be changed then, also, it would be advisable to increase the roof thickness. Both of these contemplated changes led to the consideration of the service that an open hearth roof has to withstand. The natural comparison, because of the writer's considerable experience with boilers, was to compare the open hearth roof with an arch on a boiler. It was decided that while the temperatures attained in open hearth practice were equalled in modern boiler practice, there were, however, two other conditions which the open hearth roof has to withstand that are more severe than boiler practice. One is due to the fact of the reversal of the gases. This imposes a great strain on refractory material. A scouring action is also imposed on the refractory material, due to the gases passing through the furnace at a relatively high velocity and carrying with it particles of foreign substance. When it was considered, however, that in modern boiler practice sprung arches were no longer used and furthermore that in some of these large boilers severe service was imposed on these arches, we found it necessary to give considerable weight to the consideration of some other means of relieving the individual bricks from the strains imposed upon them due to a sprung roof. For the following reasons we decided to adopt a suspended type of roof:

1. Suspended arches in boilers have become a universal practice.

2. Some of these large boilers are operated at high ratings and efficiencies, imposing severe service on the arches and the fluctuating loads taken by some of these boilers, while not as severe as the constant reversing of gases in an open hearth furnace, imposed a service on the roofs that in some respects was comparable to open hearth practice.

3. The use of a suspended roof relieved the individual brick of any compression strain due to the constant expansion and contraction of the roof.

4. The suspended roof removed the weight and thrust of the roof from the front and back walls.

5. It would be possible to make repairs on a suspended roof in smaller sections and with greater ease than on a sprung roof.

6. There would be no danger of the entire roof collapsing if any portion of it failed.

In the adoption of the suspended roof no changes were made to the binding. Due to this binding restrictions were placed upon the manufacturer of this roof, limiting him somewhat, as to head room, and in the way of design in order to conform to the present roof binding. The manufacturer had had no previous experience in the application of roofs to open hearth furnaces, and it was realized at the time that the first installation was considerably in the nature of an experiment. The tile used were silica tile, each tile having a center T-slot. The total depth of these tile were 12", giving approximately 9¼" of refractory material from the inside of the tile to the slot. The shape of the arch was sprung to suit the exact shape of the former sprung roof. These tile were supported by castings, which, in turn, were suspended from rods and they, in turn, were hung from the present steel binding. At certain points repair castings were provided to make it possible to repair the roof. An expansion joint was provided directly in the center of the roof. This expansion space ran lengthwise of the furnace from end to end walls, and was covered over with a course of silica brick. Additional expansion joints were allowed in the length of the arch, running from front wall to back wall. These joints were all covered over with courses of silica brick.

This roof was put in service and the first failure occurred along the back wall at two points. This failure was due to the fact that the back wall had opened up along the skew back line, allowing some of the heat to get in around the back of the tile,

burning a few of the castings. This failure occurred after 125 heats. The roof was patched by the regular crew of brick masons very easily. The second failure occurred after 180 heats. This consisted in a portion of the roof burning out at the center of the crown, and it was felt that it was due entirely to the open expansion space. This consisted of a patch of about 4 ft. x 6 ft. and was also readily repaired by the regular crew of brick masons.

After this roof had been on for over 200 heats, it was decided that a complete rebuild would be made on this furnace, and at that time we had reached the conclusion that it would be advisable to try a roof that was perfectly flat from front wall to back wall. We had also reached the conclusion at that time that the design of the roof could be improved.

1. By increasing the total depth of the tile from 12″ to 15″.

2. By making some better provision along the front and back walls to facilitate repairs.

3. It was felt that a flat roof would in some measure reduce the scouring of the roof along the front and back walls because of the opening up of the space which would reduce the gas velocity at these points.

At the end of 247 heats the complete furnace was taken out of service. At that time a considerable portion of the roof over the bath needed repairs. The portions over the ports were in excellent condition.

At the present time we are arranging to make the followiing installations of suspended roofs. On No. 2 furnace, which is the furnace on which the trial installation was made, we are installing a flat suspended roof. This roof will be flat from front wall to back wall, but from end wall to end wall will still maintain the knuckles over the ports. The total depth of the tile will be 15″. Proper provisions have been made in the design of this roof, so that repairs can easily be made at well selected points. The weight of the entire roof is taken off the walls. The entire walls can be removed without in any way disturbing the roof. Proper provisions were made for the expansion and contraction of the entire roof without allowing open expansion spaces. This roof is now being erected.

No. 1 furnace, which is the furnace next to No. 2, is, to all intents and purposes, exactly the same as No. 2 furnace. However, on this furnace we have restricted ports. Therefore, it has been decided that we will take all of the castings that were used on the trial arch installation on No. 2 furnace and use them for the roof over the bath only on No. 1 furnace. This arch will be arranged with tile of 15″ total depth. The design will be such so that repairs can easily be made at well-selected points. The material for this roof will be on the ground in the next week or two and we expect to have this roof in service within the next thirty days. We, therefore, feel that within the next six months we will have an excellent opportunity to determine the advantages, if any:

1. Of a flat roof over an ordinary sprung roof;
2. Of a flat roof over a suspended sprung roof;
3. Of a suspended sprung roof over an ordinary sprung roof.

With the data we will obtain we believe that we will be able to determine the relative merits of the different constructions and settle, in our own minds, the proper kind of roof construction for our open hearth furnaces. We regret that we cannot, at this time, give you the results of these installations, but this data will be available to all engineers that are interested at a future date.

Refractory Problems By-Product Coke Plant

By MARTIN J. CONWAY*

GENERALLY speaking, the refractory problems in the design of a by-product coke plant are less severe than the remainder of the steel plant, but while this phase of the industry is practically in its infancy compared to most of the other operations, the problems of material and design seemed to have received more practical attention.

The following table has been compiled from the proceedings of the American Society for Testing Material, held in June, 1925, and describes the kind of refractory used in the construction of by-product ovens, together with the approximate load and temperatures that the brick are subject to.

The modern coke plant consists of a number of rectangular coking chambers, measuring from 20 to 30 feet in length, 10 to 12 feet in height, and 16 to 22 inches in width, and holding from 10 to 16 tons of coal per oven and requiring from 14 to 30 hours to coke the charge, depending upon the oven width, flue temperatures, thickness of flue walls and the demand for coke and gas. One inch per hour being considered as good coking practice, although this rate is often exceeded, especially in the more modern plants.

The oven is heated by gas, burned with preheated air in flues at the side and bottom of the chamber, which may be vertical, as in the Koppers ovens, or horizontal, as in the Somet Solvey ovens. The coking chamber should, therefore, be as gas tight as possible, as on the inside of the oven a reducing condition is maintained as against an oxidizing condition in the flues surrounding the oven.

This gas tightness is chiefly effected by the use of flue blocks of special design, which form a gas-tight joint and give maximum strength.

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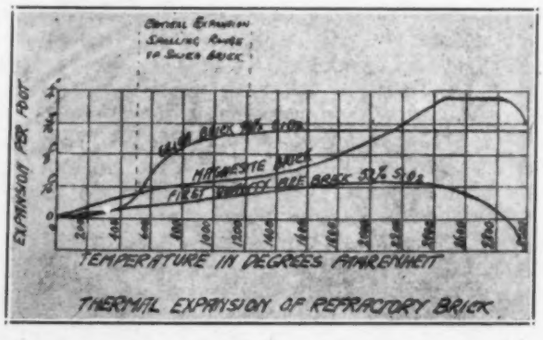
In general practice, the fuel walls, which are constructed of silica, are not subjected to a great deal of abrasion due to the fact that the coal contracts in coking, and the ovens are constructed with a slight taper, being larger on the discharge side. There is an abrasive action on the floor of the oven during the time of pushing, and this service is met by the use of fire clay blocks for the bottom of the oven chamber. In addition to its efficient heat conductivity, silica resists the action of the salts which may be present in the coal. Probably the greatest strain the battery of ovens has to stand is during the starting-up period. Should the battery be heated too fast, cracks would form, due to the rapid expansion. After the ovens are in operation, the individual chambers are subjected to rapid cooling when cold, moist coal is dropped into the red hot chamber.

CLASSIFIED OF REFRACTORIES FOR BY-PRODUCT COKE OVENS

Part	Material Used	Maximum of Temp.	Slagging	Load in Lbs. Per Sq. In. As Given For: Kopper Ovens	Semet Solvey Ovens	Abrasion	Spalling
Foundation Mat	Clay	1830	No	25-30	Important	No	No
Main Flues	Silica and Clay	1300-1400	"	16-20	"	"	"
Lower Bench Walls	Silica	1330	"	18-20	"	"	"
Korbels of Checker Chambers	Silica	1830-2350	"	20-25	"	"	"
Checkers	Silica and Clay	1830-2730	"	8-10	No	"	"
Inside Curtains Walls	Silica	1830-2550	"	———	"	"	"
Outside Curtain Walls	Clay	390-1330	"	———	"	"	"
Upper Division Walls	Silica	1830-2550	"	12-15	Important	"	"
Flue Blocks	Silica	2190-2730	"	———	"	Important	"
Oven Chamber Floor	Clay	1830-2190	"	3- 6	No	"	"
Oven Roof	Silica	1830-2190	"	6-10	Important	No	"
Oven Roof Ends	Clay	1830-2190	"	5-10	"	"	"
Charging Holes	Clay	1470-2190	"	———	No	Slight	"
Jamb Blocks	Silica and Clay	1830-2730	"	15-20	"	Important	Important
Top Mat	Clay	1110-1830	"	5-10	"	No	No
Stack Lining	Clay	500- 700	"	———	"	"	"



THERMAL EXPANSION OF REFRACTORY BRICK

FIG. 2

The following curve has been prepared, showing the relative expansion of the silica brick, as compared with clay and magnesite brick.

As shown by the table Fig. 1, the jamb blocks are subject to abrasion due to the doors being lifted and replaced, when the ovens are discharged and charged. The charging holes are also subject to some abrasion, but these are usually formed with clay blocks capped with a cast iron rim.

Modern coke ovens of the Becker type, shown in Fig. 3, are constructed entirely of silica from the base of the regenerators to the top of the cross-over flues. The shapes used in the construction are carefully made by hand-molded process and are tested, special care being given to the grind and burn.

Because silica will withstand high temperatures, it is possible for the oven flue to reach as high as 2730°F. without danger of failure, thereby allowing oven construction which produces coke faster than is the practice on the older type of ovens.

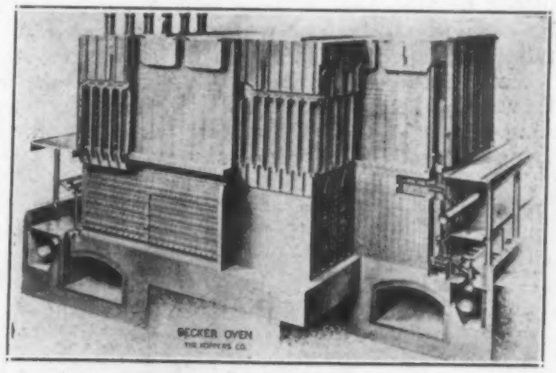


FIG. 3

In general, the outstanding feature of coke oven chamber construction is the use of shapes which are designed to give a thin wall of maximum strength and gas-tight joints, and no doubt this feature could profitably be incorporated to a greater extent in the design of steel plant furnaces.

*Gas Producer Operation**

By F. E. LEAHY†

IN a large majority of metallurgical operations using furnaces for production or heating it is necessary to use a gaseous fuel. This is due to the high furnace temperatures or close regulation, or where a solid fuel could not be used for various economical reasons.

The low cost of producer gas compared to any other available gases makes it the most desirable fuel for general use. We, therefore, find almost a universal application of gas producers throughout the various manufacturing industries.

A number of papers have been delivered in recent years before various engineering organizations, describing the improvements that have been made in the design and construction of Gas Producers. Progress has been made in increasing the rate of gasification, maintaining a uniform quality of gas of high calorific value, and coal and coke of most all grades have been successfully gasified.

Now that the producer has reached such a stage of advancement, why not copy the method of maintaining these results in daily practice by adopting the methods of control now used in modern boiler plants.

In this paper will be outlined some results obtained from recording instruments installed to guide the operators and check the practice, to secure results in daily practice close to what are obtained on tests made under skilled observers.

It is possible to obtain in modern producers a rate of gasification of 2,000 pounds of coal per hour, or higher. Assume the coal contains 13,500 B.T.U.'s per cubic foot, a boiler consuming the same amount of coal per hour at 70% efficiency would develop a boiler horsepower on 33,479 divided by 13,500 times .7 or 3.54 pounds of coal per boiler horsepower which is equal to 2,000 divided by 3.54 = or to 565 boiler horsepower. At the present price of fuel we cannot afford not to carefully check the operations of a fuel consuming unit of such size as in the case of all boilers we use sufficient instruments to intelligently direct the operators to obtain the greatest economy. But a boiler can at the worst merely increase the cost without seriously affecting the output of the plant, while the faulty operation of the Gas Producers may seriously impare the quality and quantity of the product. For this reason, the gain in a producer plant over a boiler plant is greater, if faulty operation can be prevented and good operation uniformly maintained. Most investigators to date have worked on improvements to the equipment to obtain the results and overlooked the necessity of providing, as now done in modern boiler plants, sufficient instruments to guide the operators and check the practice.

Gas House Labor

The labor available for gas makers and cleaners, is such that it is generally impossible to obtain any but what are generally known as common labor. The tasks are laborious, hot and dirty and require strength as the first requisite. They can be educated and are usually willing to co-operate to secure better results and can usually be depended upon if given assistance. They can be favorably compared to the general boiler house labor in intelligence and if given the opportunity will equal their performance.

Producer Gas.

Producer Gas can be defined as the product obtained from blowing a mixture of steam and air through a bed of hot coal or coke. The gas obtained is a combination of carbon and hydrogen in the form of carbon monoxide, hydrogen, carbon dioxide with some higher hydro-carbons in a small quantity, depending on the grade of fuel used. In the operation of a producer, coal or coke is fed from the top and a blast of steam and air is blown through the fuel beds. This, of course, applies to the so-called pressure type of gas producer. For the various reactions that take place in a producer in the production of gas, the reader is referred to the many articles already printed covering the subject Only the features that affect the operation will be discussed in this paper, and especially those, which we propose to control.

The Blower

The blower may truthfully be called the heart of the producer and failure on the part of this most important element will immediately be reflected in the quality of the gas produced.

The gas makers usually believe, and rightfully so, that the shutters on the blowers controlling the amount of air admitted to the blast are a good thing to keep closed or nearly so, to avoid the formation of clinkers and hard poking and in many plants this is the practice usually discovered. Of course, the result is a gas of poor quality.

In the pressure type producers the blast is furnished by either a steam injector, a fan, or turbo blower type blower.

The steam injector type aspirates the air and with the steam used for aspiration furnishes a mixture of steam and air. For uniform operation the steam air mixtures should remain constant at all capacities, which would be indicated by the temperature of the blast remaining constant. This is to maintain a constant relation of pounds of steam used to coal gasified. Some steam aspirating type blowers are capable of approaching this requirement very closely, a test of a blower recently made, resulted in a saturation temperature within a few degrees of 125° F., over its operating range. Some others tested were capable of maintaining a close temperature over their operating range, but the minimum temperature that could be obtained was 130° F., and in another case 135° F. This, of course, limits the quality of gas obtainable as for any fuel there is a saturation point which if exceeded results in a gas produced of lower calorific value than actually possible to obtain.

*To be presented at 22nd Annual Convention AI&SEE at Chicago, June 7-10.

†Power Engr., Pgh. Plants, National Tube Co., Pittsburgh, Pa.

Data can be obtained from the builders of blowers on the various blowers now used, or a test can be run to check the blowers and determine if the producer is being limited by a blower not capable of delivering the proper blast temperature.

The advantage that the steam injector type blower has in first cost and maintenance over the fan or turbo blower types has delayed the general use of this very attractive development for producers. For a discussion on the results that can be obtained from this type of blower the reader is referred to a paper read before this society June, 1924, by Mr. W. P. Chandler, Jr. By using a turbo blower any desired saturation temperature may be obtained and maintained, a condition that cannot be secured from the steam injector type blower. Mechanical difficulties have in some cases prevented this type of blowing being universally adopted, but this will no doubt be overcome and then we can expect more general application of the turbo blowers. The importance of the blower operation justifies a close check on the settings and the regular practice of checking the blast temperature will result in a gas of uniform quality.

A steam flow meter can be used to measure the steam consumed by a blower or the total steam to the blowers in a producer house in which the steam of all blowers are taken from a common steam main. As the coal gasified is proportional to the steam used, the meter can, by knowing the ratio of steam to coal, be used by interpolation as a fuel meter. Knowing the coal consumed and steam measured gives a quick check on the blower operation. The advantages of using this meter to approximate the fuel consumption and demand rate will be discussed later in this paper.

Discussion of Charts Obtained From Steam Flow Meters and Pressure Recorders.

The charts shown on Figure No. 1 were obtained from Gas House No. 1. This Gas House contains nine Hughes Producers, each rated at 2,000 pounds of coal per hour. The Producers are equipped for automatic coal feed and ash removal.

Steam to the blowers is automatically controlled from the gas pressure. Each producer is separately driven by a motor, the control of which is through a push button for starting and stopping.

Chart No. 1 was obtained during a period when a bell float, not compensated, was used to control the steam to the producers. This float controls all the steam to the producer house. The chart, which is a record of the steam flow, shows the wide variations in the rate of flow. The float was changed, as shown in Figure 7, to the compensated type and after this was done, Chart No. 2 was obtained and shows a typical chart obtained during a normal operation. Any abnormal periods of operation are immediately reflected on the chart. From this chart can be noticed the difference in demand for gas between the day and night turn; also, the rate of gas flow between turns, as well as the regularity of the operation.

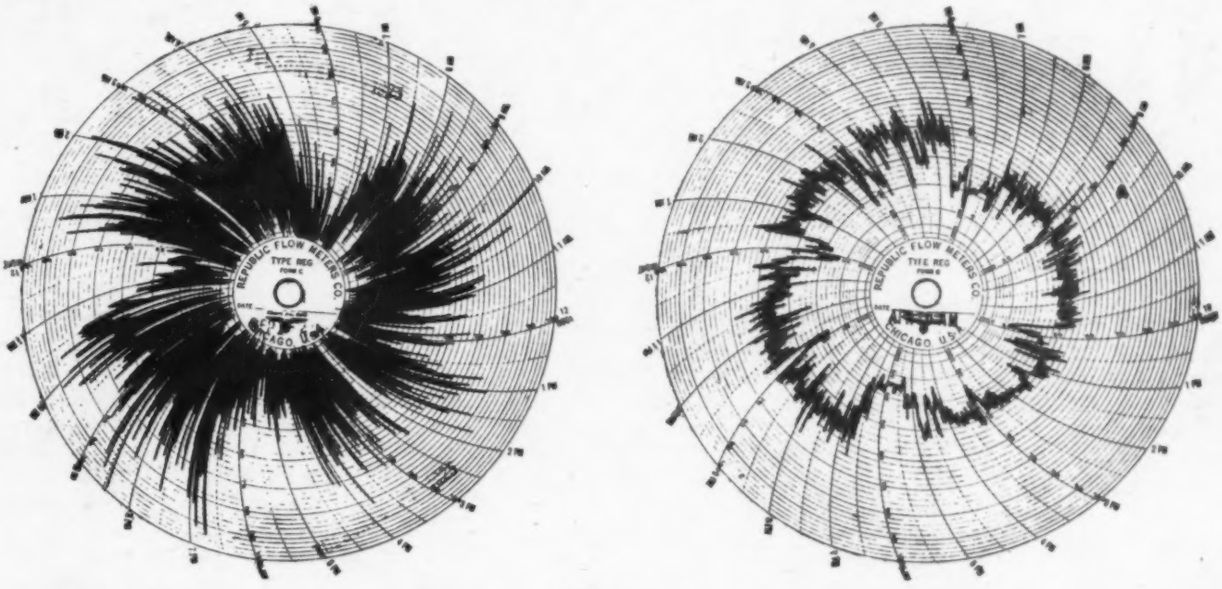


FIG. 1.

The charts shown on Figure No. 2 were obtained from the same gas house and correspond to the steam flow meter charts shown on Figure No. 1. From these pressure charts, which are a record of the steam and gas pressures, the effect of the pressure changes are not so clear as the flow meter charts. In combination with the records from Figure No. 1, it is possible to analyze the conditions and locate irregularities in the operation for the 24-hour period these charts cover. From these two figures, it can be seen the advisability of using the steam flow meter with the pressure recorder for determining the correct characteristics of the automatic steam regulator.

The charts shown on Figure No. 3 were obtained from Gas House No. 2. This Gas House contains 8 Forter-Miller gas producers, 7 of which are hand-poked and fed through a hopper, and one Forter-Miller producer, equipped with a Chapman top, with automatic coal feed and agitator. The coal is delivered from an overhead coal bunker through a chute to the hopper. Steam to the blowers is controlled automatically by a float regulator, the same as No. 1 Gas House. Chart No. 1 was

obtained while using a float that was not compensated; Chart No. 2 was obtained after the compensated float was installed. Chart No. 2 is typical of normal practice and the variations are due to a combination of opening and closing the gas valve on the furnace frequently and the variations in gas pressure due to the opening and closing of the coal hoppers during the feeding of the coal. The rate of flow between turns and demand of each turn, as well as the regularity, are clearly shown on this chart.

These charts were taken on No. 2 Gas House and are the pressure charts corresponding to the flow charts shown on Figure No. 3. These, also, help to emphasize the necessity of the complete record obtained from both Figures No. 3 and No. 4 to analyze the conditions existing in the gas house. The effect of regulation can be noticed from the charts and, particularly, the effect of hand-charging shows up clearly by the frequent and rapid changes in the gas pressure lines, and not quite so marked on the steam pressure record. The effect of these pressure changes can be noticed on steam flow charts, Figure No. 3.

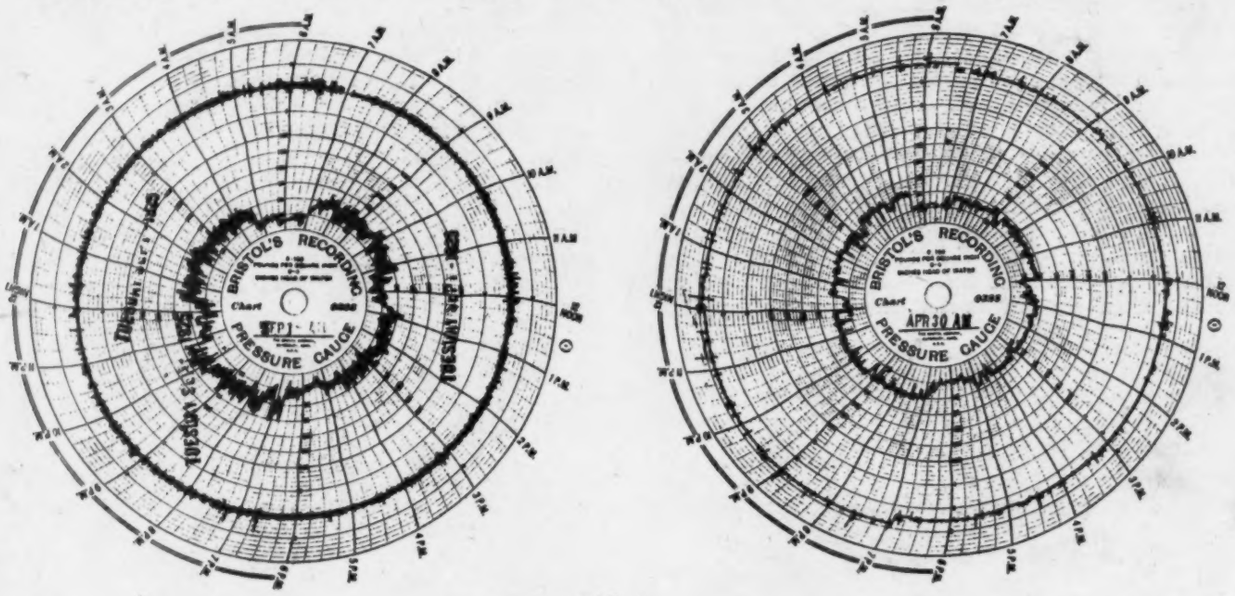


FIG. 2.

The charts shown on Figure No. 5 are records from a recording pyrometer located in the gas flue leading from the gas house and give the temperature of the gas leaving the producer house.

Chart No. 1 was taken before the foremen were instructed to work to a closer temperature range. The heavy line is the 1500° F. temperature line.

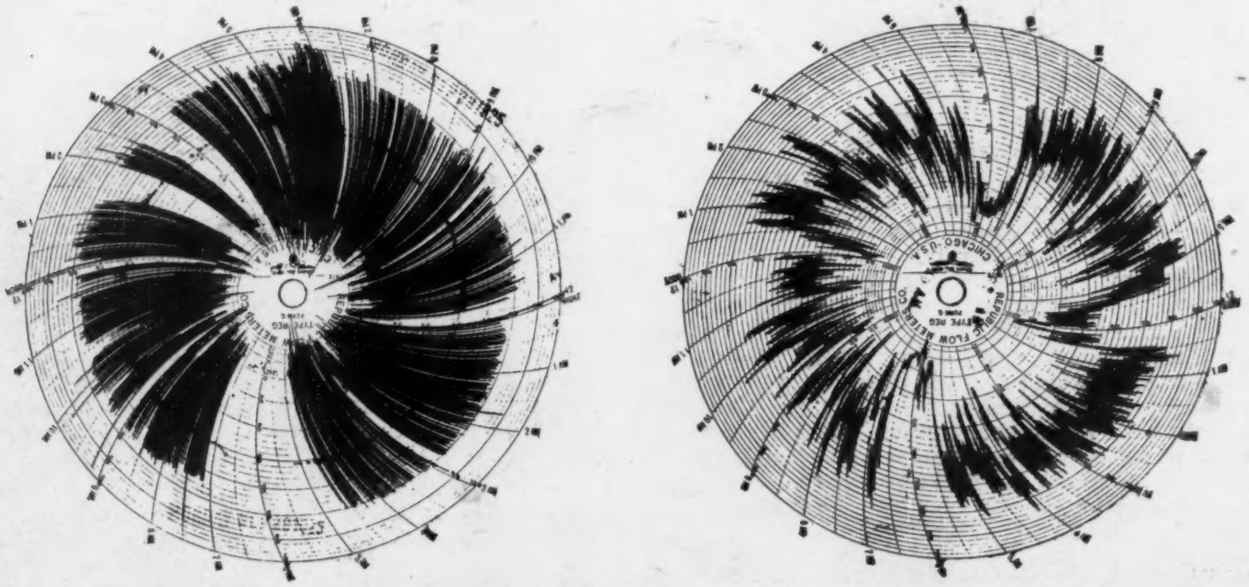


FIG. 3.

Chart No. 2 was taken after the foremen were instructed to make gas as close as possible to 1500° F.

One turn requested that gas be made at close to 1600° F., the other turn requested 1500° F. The

charts show how close it is possible to work.

This chart serves as a record of the gas house operation and shows how close the coal feed is proportional to the load. If too much coal is charged, the temperature drops and, if not enough, the temperature increases. The advantages to having such data for referenc is self-evident. On different grades of coal some different temperature might be required and having such a record a continuous chart is maintained on the gas house operation.

The charts shown on Figure No. 6 are the records taken of the gas temperature from individual producers and show the range of temperatures that take place in the regular operation of a producer. They show clearly the advantage of keeping the top temperature of each producer, as well as the temperature of the gas from the house.

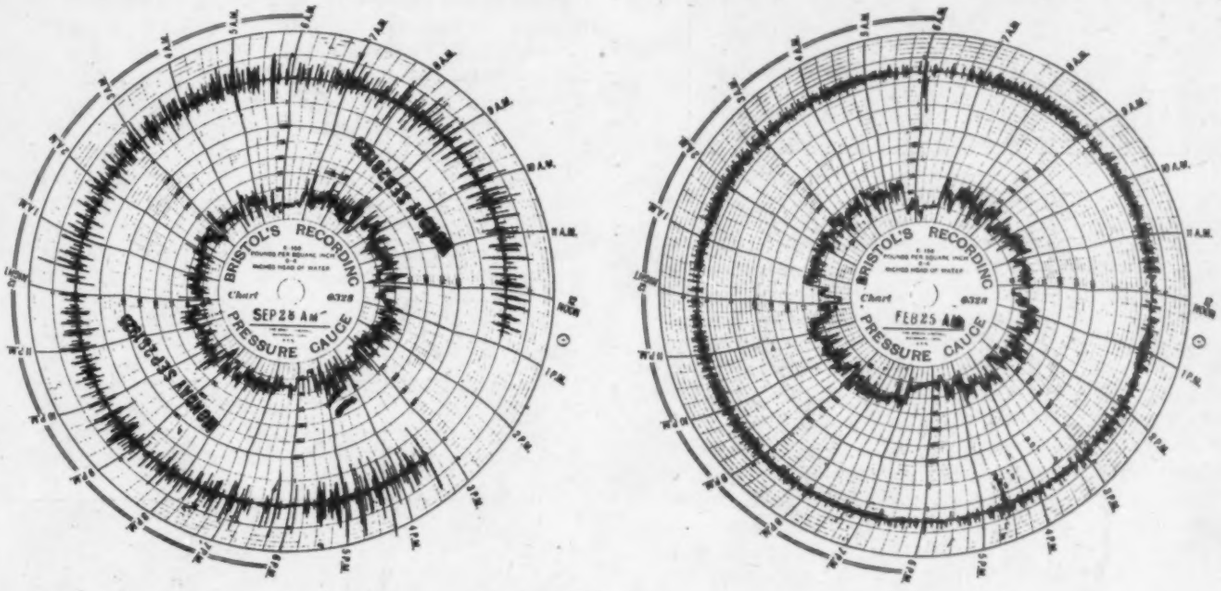


FIG. 4

Chart No. 1 was taken from No. 3 producer, and Chart No. 2 was taken from No. 2 producer. On Chart No. 2 a peak temperature of 2000° F. can be observed. This was one of the first temperatures taken here on an individual producer, and when it was noted, the operators immediately made the necessary changes to secure a lower temperature.

Instruments and Use

The first instrument recommended is a pressure gauge, preferably a combination type to show the pressure carried on the blower or blowers, and the gas pressure in the main. This will give a working knowledge of the pressure conditions.

The second instrument should be a steam flow meter, from which can be obtained almost a complete story of the operation of the producer and furnace, steam used and by interpolation the coal consumed, the extent and duration of the peak loads, etc.

The third instrument would be a recording pyrometer on the outlet gas to watch the uniform working of the producer; from this can be checked the regularity of coal feed to load, prevention of blow holes and general fuel bed conditions.

In a battery, if it is desired to know the proportion of the load carried by each producer, an orifice disc in the line can be installed and a simple manometer used if a separate flow meter should not be desired.

The blast temperature should always be available and some type of distant recording type would be preferable to enable the reading to be made at the firing floor level.

In many plants at the present time a manometer for reading the gas pressure and a steam pressure indicating type gauge is the only equipment now used. Though the above recommendations may seem extreme, I need only recall that the same conditions existed in most boiler plants some years ago, and today they are well equipped. As a guide to what may be obtained, start with a recording gas and steam pressure gauge, a steam flow meter and a pyrometer on the outlet gas and see what you learn.

Automatic Operation of Producer

At the present time, all stress is being placed on the advantage of uniform feed in preference to the former practice of hopper feeding, and the results obtained justify the claims made for the uniform feed.

There is another feature in this connection that now the automatic feed and poking or agitating are well established that should be considered. The speed of coal feed and poking should be made automatic and bear a direct relation to the quantity of gas made by slowing down and speeding up by some automatic control, the same as now done in all underfeed coal equipments. This can be regulated from the steam flow and the gas makers attend to such minor adjustments as are required to keep the fuel bed uniform.

Effect of Steam on Gas Produced

It is well known that approximately .4 of a pound of steam or lower per pound of coal will produce the best results in average practice and

that an increase above this amount results in a decrease in CO and an increase in CO_2 and H_2. As steam is increased above this amount, more steam is undecomposed, so that the amount of undecomposed steam in the gas increases rapidly, assuming the fuel bed thickness remains the same.

Another factor enters into how close this figure may be approximated and that is the fusibility of the ash in the coal. It may be necessary, in order to obtain continuous operation of the producer, to raise the ratio of steam to coal to as much as .6

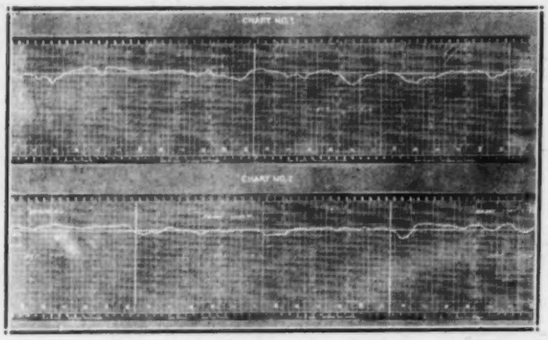


FIG. 5.

of a pound of steam per pound of coal to get continuity of operation. This, of course, will be reflected in the calorific value of the gas. Careful supervision will determine this and the blowers can be adjusted accordingly. It is sometimes customary to check the operation by running a bar down through the fuel bed to determine the different zones and thus judging the operation of the blower.

Many operators judge the quality of the gas by the color of the gas and try to obtain a creamy, yellow, smoky color. If they do not obtain this, the condition of fuel bed is inspected and, if hot spots or channeling are noted, they are corrected.

Gas Temperature

For any fuel, the temperature of the gas will remain constant, so long as the operation of the gas producer is normal; that is, no change in fuel bed thickness or blast temperature. The calorific value will depend on blast temperature, increasing with a decrease in blast temperature. For this reason, it is important that some means be provided to measure this temperature to enable the operator to quickly detect any change from a normal working condition, so that he can immediately correct the trouble before the gas is affected. The abnormal working will affect the producer efficiency, furnace efficiency and the flame temperature, depending on the degree it varies, as a rule, by running the producer cold the per cent of undecomposed steam will increase, the calorific value of the gas decrease and the cu. ft. of wet gas will increase due to the increase in moisture undecomposed.

By using a recording pyrometer and observing the temperature of the gas obtained during periods of good production, and the same during periods of poor production, the best operating temperature can soon be determined. This, of course, can be checked by calculation of the flame temperature possible from the gas analysis, but, in this connection, it sometimes is desirable to run higher than theoretical in order to prevent tar condensing in the flues and checker chambers.

It will soon be noticed that there is a minimum temperature lower than which it is not desirable to go, as the furnace practice will be immediately curtailed. There is quite a range above the minimum working temperature where the furnace efficiency will be good and for Pittsburgh coal a safe operating range will run from 1300° F. to 1600° F., with the most desirable temperature close to 1450° F. It is hardly necessary to mention that any attempt on the part of the gas makers to maintain the temperature by permitting holes in the fire to pass air through and burn the gas should be promptly discouraged.

Another period that should be closely watched is the cleaning of the producer. If, after cleaning, the producer should be put back on making gas too quickly before the fuel bed has been properly conditioned, the top temperature will indicate a reading amounting, in some cases, to as much as 2000° F. By watching closely the producer can be put back into operation without any disturbance to the quality of the gas by increasing the blast slowly for an hour to two hours after the cleaning has been completed. As high temperatures and poor gas analyses go together, this is a very effective way to guide the operator in his duties. Most writers on gas producer operation have emphasized the value of knowing this temperature and the importance of this reading and, yet, it is still but rarely used in daily operation.

It is as important to gas producer operation as a pressure gauge is to a boiler. One of the probable handicaps to the more universal measuring of this temperature has been the difficulty of securing a reliable pyrometer, but fortunately today this no longer exists.

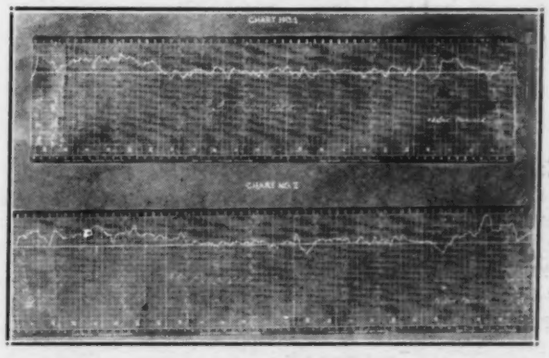


FIG. 6.

If a gas maker has any difficulty maintaining the temperature, he can call attention to this and an investigation will soon disclose the cause of the trouble.

For the reasons outlined, it can be seen that where uniform quality production of gas is desired, it is essential that this temperature be known by all concerned in the gas house operation.

Regulation of Steam From Gas Pressure

Many plants now use automatic regulation of the steam to the blower by means of a type of bell

float regulator. This is used for automatically controlling the steam to obtain a constant gas pressure. At our plant, we used a bell float type, designed and installed by A. Steinbardt in 1907 and used until recently, but when the steam flow meter was installed we discovered that the regulator was too sensitive and in maintaining a constant gas pressure large peaks of steam flow were required. This float was replaced with one having a choking effect, which permits a greater variation in gas pressure, but reduced the peak flows of steam.

The steam pressure would vary sharply from 30 to 75 pounds steam pressure, but when the dampened regulator was used from 15 to 20

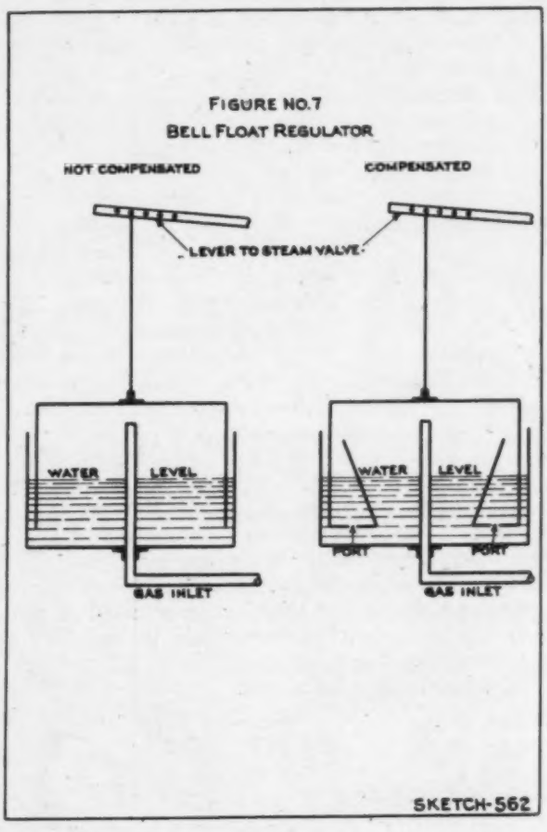


FIG. 7.

pounds lower peak pressures were obtained without any noticeable effect on the furnaces. By reducing the peak, it will also reduce the quantity of soot blown over and obtain a much better condition in the producer.

Furnace Operation

As the results obtained in the gas house are reflected in the furnace operation, it is proper that some mention should be made of the furnace operation.

The remarks will be confined to regenerative type furnaces as the majority of applications of producer gas are on this type of furnace. As each furnace is equipped with air and gas checker chambers, it is important to make regular inspections of same to make certain that they are operating uniformally.

In starting up a cold furnace, the best practice is to put the furnace on gas during the middle of the week, so that it will not be too long before a complete and thorough burnout is obtained. This will prevent it from blocking up with soot and tar, which may occur if furnace is put on gas too long before a burnout.

Another very particular time that good control should be exercised is between turns and during periods when the furnace is not producing. Care should be taken to see that the amount of gas used is not too low or too high, and it should be fed to the furnace uniformally. That is, a lot of gas should not be turned on for a couple of hours and then reduced too low for another period. After the quantity required has been determined, the operator should be guided by the meter, as it is difficult to judge entirely by observation.

The same remarks apply to week-end periods when a furnace is shut down during the period of the burnout and placed in operation again sometime later. As a rule, experienced furnace men are capable of judging the amount of air necessary for the amount of gas used, but it is their judgment of the quantity of gas that is apt to be faulty. If too little gas is used there is danger of the checkers chilling and filling with tar and soot and blocking up; if too much gas is used, it is an unnecessary waste. The gas pressure required for the correct operation of the furnace is a function of the gas flue area, length and valve area, and by trial the correct pressure can be determined and then maintained. This may range from 1" to 3" of water pressure. When gas flues are small it may be necessary to increase the gas pressure during the latter part of the week to overcome the resistance of the tar and soot deposited.

Conclusion

In conclusion from the data presented, it is essential for uniform operation to equip the gas producer house with sufficient instruments to guide the operators and check the variations in practice. The number and kind used should be sufficient to enable the operators to keep their practice uniform and as close to the ideal as possible with the fuel and equipment available.

Automatic control should be extended to include agitation and coal feed to proportion the poking and coal feed to the load on the producers.

The instruments recommended will not only be a help in the operation of the producers, but can be used to analyze the furnace operations, to determine the magnitude of the peak loads, occurrence, comparison of day and night turns and fuel required per ton of output, as well as the best gas for the operations.

The methods now in common use in most of the large boiler plants can be copied and utilized in the daily operation of a gas producer plant.

The operation of automatic regulators available at present for the control of producers should be investigated to determine if their operation is correct for the producer installation; to determine if it has the proper degree of sensitivity and, where necessary, the proper dampening provided.

Continuous Bloom and Billet Heating Furnaces

By E. W. TREXLER*

THE design of a furnace plays a very important part in the life of the refractories with which it is built.

The proper furnace proportions as to size of combustion chamber, height and type of roof, proper size of gas passages, type an dlocation of burners, length of flame, type of fuel and last but not least, a practical means for the removal of cinder, all play a very important part in the maintenance costs of heating furnaces.

The temperatures prevailing in most heating furnaces are not as high as those in our melting furnace, but nevertheless for various reasons the maintenance is often high.

On old furnaces, many of which have too small a combustion chamber, the refractory life is surprisingly short, especially with direct coal firing, some of them needing replacement every six to eight weeks, while on the later furnaces, where the design has been better, the roof will last a year or more without extensive repairs. The same is true of old gas fired furnaces, the roof lasting from four to six months, while with the modern furnace there is no disintegration of the roof noticeable after six months' operation. All tending to show what an important part design plays in the life of refractories.

In the past, because of short life of refractories, water cooling has been employed to reduce replacements. Water cooling of roofs has now been eliminated in later furnaces and the flat suspended roof is giving us very satisfactory service on continuous bloom and billet heating furnaces.

The hearth of the furnace is the point of highest temperature and, therefore, highest maintenance due tto cinder erosion and abrasion in removing it. Here again, in most cases, water cooling is employed. We believe the better method is air cooling by drawing the air for combustion through passages underneath the hearth and thus heating the air and cooling the hearth enough so that the cinder does not adhere and is easily removed.

What we would like to see is a hearth without any cooling but built of a refractory material to which the cinder will not adhere and the life of which will compare favorably with the rest of the furnace. Can the refractories manufacturers give us a refractory material that will fill these requirements?

The most important water cooling employed in our continuous furnaces that heat larger sizes of blooms is the water used in skid pipes. These cold skid pipes are a detriment to efficiency. They affect the quality of our steel because of the black spots left on the heated billet and we also require a longer hearth in our furnace because of them. Their replacement and repair is often a difficult and trying job. We know of one large continuous furnace that has been operating for several months without skid pipes and is still satisfactory. The indications are that the efficiency will be a great deal better than a duplicate furnace employing skid pipes and the heated bloom from the former furnace is much more acceptable to the mill operators.

Can the refractory people develop a refractory furnace skid or furnace bottom on continuous furnaces that will compare favorably with the water cooled skid pipes?

The elimination of water cooling in heating furnaces is important from the efficiency standpoint as the heat absorbed by the cooling water is from 2% to 5% of the total heat supplied by the fuel.

Very gratifying strides in the design of continuous heating furnaces have been made in the last few years, but we must now have the co-operation of the refractories men in order to eliminate the wasteful water cooling which is employed in practically all steel mill furnaces because the refractories have not withstood the hard usage and temperatures incident to the manufacture of iron and steel.

*Combustion Engineer, Bethlehem Steel Co., Johnstown, Pa.

THE BIG FOUR OF SAFETY

(Continued from page XV)

out and not worked out and applied result merely in dreams and visions which are unstable and are dissipated like the mists of the morning. American industry has then in safety a balance wheel helpful for efficient production and for contented workmen, which is a combination impossible to equal or excel. Let us examine the "Big Four" in detail and see how this has been brought about.

Contact

Safety has brought the boss and the workmen together again. One of the perils of big business has been the removal of the head of the concern from the plant to the "city" or general office, a dozen or a hundred miles away. The contact is broken and the personal touch which is so valuable does not exist; but Safety, which cannot exist without personal contact between men, comes to the rescue. A story will illustrate my point: One of the larger plants of a company manufacturing iron and steel, and employing approximately fifty thousand men, decided to have a "No Accident Month" recently. One of the features in connection with the campaign was a rally of the superintendents, foremen, gang leaders and key-men in an auditorium located in the mill town on the evening preceding the drive. About one thousand men were in attendance; men from the mill whose only contact with the "big boss" (the President of the concern) had been to see his photo in the newspaper or his name on a letterhead. He meant nothing vital or nothing real to those mill men—just a figurehead or just a name. That flimsy contact was changed at the Safety Rally however, for he appeared on the platform and gave his endorsement to the Safety Drive in no uncertain terms.

Through safety a contact was established between the president of the concern and one thousand men in one of his larger plants that promises much for production and for safety.

Conference

When men come in contact with each other, if they are at all human, and most steel mill men are, it results in a conference—they are brought together; and so the president and one thousand of his men had a conference that evening. Of course, the main topic was Safety, but safety has many ramifications. It goes beyond the individual man. It links him to his fellow men, to his foreman and to his superintendent. It goes beyond the confines of the plant, into the workman's home. It enters the school room where his children study and goes out on to the street where they play. It enters the inner sanctuary where his ideals are—love of home, of children, of parents and of friends. All these constructive things which make for good homes, good citizenship, effective production and safety were discussed at the conference that evening, and the men went home thinking about the serious things of life which, after all, was the intent and purpose of the meeting.

Confidence

As long as the world goes round the thing that will keep it revolving will be the confidence or faith. Of course, the material world will continue to revolve as long as natural law exists, but the world of human beings, the world of our day and our civilization is founded on and exists by confidence. Wherever two people live or work together there must be mutual confidence in each other. If ten thousand people live in the same town or work in the same industrial plant the confidence must be broadened and deepened until the entire ten thousand are included. Should these ten thousand people try to live as individuals entirely their existence would be very short. Confidence cannot be engendered, however, unless there is contact and conference. Confidence or faith in people comes because people get together and learn to know each other. The writer was employed during his youth in a Bessemer department of a steel mill. At certain times the molten iron received from the blast furnaces contained a large amount of slag. This would slop over the converter into the pit, and the plant would have to be shut down frequently to clean up. On these occasions the men would remark that the blast furnaces were making rotten iron. At the same time, if there was an unusually large amount of the product thrown out as seconds, the men in the finishing department would say, "The Bessemer department is making rotten steel." There was no contact between the departments and, consequently, no conference and no confidence. As the years went by a weekly meeting of the department superintendents was inaugurated. The result was they learned to know each other, to appreciate each other's problems and to have confidence in each other, which resulted in less criticism, better feeling and better product. The one thousand men went away from the safety meeting I have described with a better feeling for the "big boss" and more confidence in him. The "big boss" also went away knowing the men better and with a more kindly and helpful feeling toward them. They had been brought together because of their common interest in safety, which furnished the occasion for meeting each other.

Co-operation

A feeling of confidence in other men, who are brought face to face by contact with each other in a conference, will naturally lead to a spirit of co-operation between the parties concerned, regardless of whether the thing they wish to promote is production or safety. The men in the plant who attended the safety rally entered the plant the next day bigger, better and broader men. They had caught a new vision of the value of efficiency, as well as safety. Their work was not a mere humdrum task which engaged their attention and energy. They were now part of a great plan, members of an organization which had caught the spirit of helpfulness both to their fellow men and to the industry which employed them.

As we approach the annual meeting of the Association of Iron and Steel Electrical Engineers, at Chicago, may our contact and conference be such that it will engender confidence in each other. If we do this the ultimate result when we return to our plants will be full co-operation which will produce one hundred per cent safety and efficiency.

IRON AND STEEL EXPOSITION

June 7th-10th, 1926

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Safety--
Combustion

Everybody Welcome

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Association of Iron & Steel Electrical Engineers

Convention and Iron and Steel Exposition

June 7th to 11th, 1926.

Dear Member:

Supplementing my last letter to you of May 20th, it is my desire to give you the last minute arrangements of our Convention and Exposition.

When you arrive at Chicago, go straight to the Sherman Hotel, register and Mr. Ruel of Hotel Sherman will take care of you.

Next, go up to the Mezzanine floor and meet the registration and information chairmen, F. L. Collins, Chairman of Registration, and Jas. L. Mills, Chairman of Information.

After registering, please make arrangements to attend the Business Session to be held in the Crystal Room, (first floor above the Mezzanine floor.) The Business Session will be held at 10:00 A. M.

At 12:30 Noon, you should be on hand at the A. I. & S. E. E. general luncheon at the Louis XVI Room, first floor above the Mezzanine Floor. This luncheon is for the express purpose of getting everybody acquainted and all of the members, guests and also the exhibitors should attend.

At 1:30 P. M., you should attend the first session, being held under the Auspices of the Safety Division. Our Program for this session embraces remarks by the President of the National Safety Council, Mr. Chas. B. Scott, and Dr. Loyal A. Shoudy, Chief Surgeon, Bethlehem Steel Company.

Next, the Rules for the Safe Operation of Electric Overhead Traveling Cranes will be discussed. These rules in all probability will be adopted for use in the Iron and Steel Industry and you should be on hand to express your opinion.

At 9:00 P. M., the annual informal dance will be held. Everybody is invited. Mr. R. L. McIntosh is chairman of this affair.

For Tuesday, we have Electric Transportation day and what subject is there of more interest to us and our companies today?

Wednesday has been devoted to Refractories, Gas Producer Operation and Standardized Mill Type Motors.

Thursday has been set aside for the report of the Electric Heat Committee and a paper by the Wheeling Steel Corporation which should arouse a great deal of interest and discussion.

In connection with the Thursday Night Dinner Dance, it would be my suggestion that you secure your tickets and your reservations just as soon as you can. Tickets will be on sale at the registration desk. First come—first served. In case you desire to mail your reservations, write F. H. Kittredge, Elec. Supt., Illinois Steel Company, Joliet, Ill.

Friday is Inspection Day and what a lot of members have been asking for a golf tournament. The Gary Plant of the Illinois Steel Company will be visited in the morning. Luncheon and Dinner at the Gary Country Club. Golf all afternoon at the Club. Register with H. E. Davis for the Golf Tournament.

The Iron and Steel Engineer contains all of the official news of the Convention and Exposition, also, all of the advance papers to be presented at the Convention.

You are earnestly urged to read your Iron and Steel Engineer as soon as you receive it.

My last word to you is: Attend the Convention, attend the technical sessions and make it a point to visit each and every booth at the Convention.

Assist your officers in every way possible to make this Convention of inestimable value to yourself and your company.

Anticipating the pleasure of meeting you at the 22nd Annual Convention and Exposition, believe me to be

Yours very truly,

GEO. H. SCHAEFFER, President.